merSETA Plastics Chamber Research 2018/19

RESEARCH PROJECT TITLE:

What is the shortfall or lack of plastics technicians and plastics engineers in South Africa and what can be done to address the problem?

FINAL REPORT

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ACKNOWLEDGEMENTS

Firstly, we would like to thank the Plastics Chamber Committee for the opportunity to conduct this research and extend the work done by previous researchers. We trust that the findings and recommendations will add value to the industry and will assist in charting a way forward for skills development and education for engineers and technicians in the various plastics sub-sectors in South Africa.

In particular we would like to thank the host company, Plastics SA, who facilitated the research project. Anton Hanekom and Kirtida Bhana are thanked for their valuable insights at project inception and Kirtida Bhana for her ongoing support and introductions to companies and key people in the industry. The researchers would also like to extend their thanks to Martin Wells, Tessa O'Hara and Heather Peplow of Summit Publishing, publishers of the magazine "SA Plastics and Rubber Technology" for their assistance in providing contact details for industry interviews and ensuring all sub-sectors were included in the research design.

Special thanks to the merSETA staff for smoothly handling all the administration of the project. Hosea Morapedi (Chamber Unit Manager), Nyameka Sonjica (Chamber Co-ordinator: Planning/Committee Secretariat) and Sandile Gumede (Chamber Administrator). Thank you for always being on hand to answer the logistical questions promptly and efficiently.

Lastly, we would like to acknowledge and thank the industry and academic participants who willingly gave their time for interviews and gave us the rich and valuable inputs which form the backbone of this research report. The infectious enthusiasm and passion of everyone we interviewed in the Plastics industry was humbling. Despite the challenges faced by many, we engaged with people who have an overwhelmingly positive outlook and are committed to the long-term future of the Plastics industry in South Africa.

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EXECUTIVE SUMMARY

Introduction

The last research study by the Plastics Chamber (Garisch, 2016) comprised a study of innovation culture and capability in the plastics sector. Garisch's (2016) study explored innovative practices in the plastics sector within a global context and sought to understand skills and knowledge required to support innovation in the context of a "futures orientation linked to advanced manufacturing". Garisch's findings, after extensive and broad industry consultation, was that there is a lack of systematic research and development-based innovation and that proprietary product innovation is only 30%. From a skills and knowledge perspective, the industry felt that fewer young people are entering the sector and that there is a lack of a "skilful" pool of people to draw on.

Based on the recommendations and within the context of a global focus on Industry 4.0 and the Circular Economy, the Plastics Chamber task team recommended a research project to understand education and training provision in the Higher Education sector (Universities and Universities of Technology). Specifically, the project focused on the education and training of Technicians and Engineers in the plastics industry. The study aims to identify gaps in provision and to make recommendations to the merSETA on future interventions to support the plastics sector.

Report context and focus

The plastics industry in South Africa is far from homogenous. There are various 'sub-sectors' with different products and processes and the study sought to gain a balanced view by looking at the different manufacturing 'sub-sectors', namely; Flexibles and Packaging, Blow Moulding, Injection Moulding, Rotational Moulding and Pipe Extrusion. Industry interviews were conducted with a representative sample from the sub-sectors (where possible).

In seeking to understand the education and training provision (Technicians and Engineers) currently in place, the study engaged with Universities and Universities of Technology and a detailed quantitative study was done on the current courses (under-graduate, post-graduate and short courses) on offer. The writers believe this is the first time a consolidated picture of training provision in the Higher Education band has been collated for the plastics industry and is, in itself, an extremely valuable resource for the Plastics Chamber.

In order to offer some form of "triangulation" of the research data, in the research design, representative Industry Associations were included in the data collection. It was anticipated that associations would offer a broader and possibly less biased view.

With these three focal points (industry, higher education and associations) to the study, the research sought firstly to understand the general industry dynamics and issues as they impact the education and provision of Technicians and Engineers. This contextual understanding is a vital component in unpacking dynamics that are not always 'obvious' and seek to understand the 'nuances' affecting training provision. The study sought to understand the current employment status and trends, job titles and function differentiation, appointment and promotion criteria of personnel from an industry perspective and to identify what the current knowledge and skills shortfalls are.

The views of Higher Education institutions and the current and planned course offerings were examined in light of the industry position, specifically with respect to the preparation of 'work-ready' graduates from Universities and Universities of Technology. The study also focused on the current status of industry and academic collaboration and concludes with recommendations from all respondents on how to strengthen the supply of Engineers and Technicians in the plastics industry.

Report structure

The report is structured as follows:

Section 1 gives a brief introduction to the study and why it was commissioned by the Plastics Chamber of merSETA. The research focus, design and methodology is discussed in detail before an explanation of the data collection methods and data analysis utilised for the study. In the sample description, the report discusses the selection of respondents from different sub-sectors of the plastics industry, the selection of Industry Associations and the selection of Higher Education institutions.

Section 2 is a detailed overview of the findings of the study. The first focus area provides a contextual overview by examining the plastics industry dynamics and issues from the perspective of company respondents. The second focus area examines the current Higher Education qualifications, programme offering and research activity as they relate to the training of technicians and engineers for the plastics sector. This includes an examination of the status of industry and Higher Education collaboration with respect to education, training and research.

Section 3 contains suggestions to strengthen the supply of engineers and technicians in the plastics industry from the perspective of industry, industry associations and Higher Education.

Lastly, in Section 4, the overall discussion, findings and recommendations are summarised.

Specific Findings

Respondent views on the status of industry strength

<u>Not globally competitive</u>

Specific Finding 1:

<u>Industry lacking innovation culture</u>

The lack of innovation in the plastics industry is driven, by and large, by a pervasive 'need' for home-grown design and development. The corresponding lack of an innovation culture is decried as a critical factor which undermines industry capacity to be competitive in the global market. This results in South African companies essentially being characterised as followers or copiers of global market trends rather than inventors.

This status is specifically attributed to the:

- *packaging industry/sub-sector, who are largely followers of market leaders in respect of materials and product development (packaging or actual film), as evidenced by the limited uptake of polymer scientists and/or opportunities to apply their knowledge and expertise (with 'brain drain' cited as a critical consequence)*
- *pipe-manufacturing/sub-sector, characterised as having 'little' development and innovation and being slow in adopting new technologies*

Specific Finding 2:

Prohibitive costs of imported materials and machinery a barrier to uptake by small companies

The cost of international machinery and materials and royalty costs are prohibitive for small companies who are focused on keeping overheads and input costs down.

Specific Finding 3:

Inefficiencies costing the industry

Optimal running of machines is all-round regarded as the 'holy grail' underpinning efficiency and competitiveness BUT South African companies are viewed as generally 'exceptionally bad' at achieving this, with resultant low productivity levels and a lack of operational efficiencies undermining industry strength and global competitiveness.

The main reasons for this malaise are attributed to expertise and aptitude shortfalls on the part of technical / operational staff in the following areas:

- *Correct maintenance of machines to ensure optimal running to specification*
- *A lack of capacity for an holistic understanding of machinery and processes, particularly with regard to the 'inter-connected' impact of changes and adjustments to machine settings (operational / process optimisation and product quality enhancement)*

Specific Finding 4:

Industry lags rest of world in terms of R&D investment and innovation-promoting outputs

Compared to the situation in certain other countries, industry respondents bemoaned the lack of laboratories, which results in the country lagging behind the rest of the world in terms of research and development and testing, as key factors underpinning innovation. A lack of adequate funding or investment is specifically decried.

Specific Finding 5:

The implementation of LEAN manufacturing principles inhibit specialisation and innovation

LEAN Manufacturing results in multi-skilling and adoption of multiple production roles. This inhibits job specialisation and this has a negative impact on the capacity to support R&D, laboratory work and concomitant innovative developments.

Specific Finding 6:

"Bad" structural dynamics and business approaches undermine company effectiveness and competitiveness

Significant variations were reported with regard to 'good versus bad' structural dynamics and business approaches and their corresponding impact on companies' capacities to be competitive and successful, or not. Attention was drawn to the following key considerations:

- *An "undue" focus on the efficiency and performance of 'silo structures' within a single business foster procedural compliance and create additional administrative burdens that take attention away from core production processes, which should be the central concern*
- *Autonomous running of each company in a group of companies is viewed as essential for success. Ie. Each company focusing on its own peculiar business environment and strategy and technologies, as opposed to centralised company 'mothership directing'*

Ignorance about the (plastics) polymer industry

Specific Finding 7:

Lack of knowledge of the industry has implications for growth

A lack of knowledge about the plastics industry amongst both industry professionals and technical functionaries, as well as young people-as-prospective students/ employees, and the critical implications this holds for industry growth and strengthening in the future.

Impact of the demise of erstwhile 'strong technician training programmes'

Specific Finding 8:

The loss of the National Diploma in Polymer Technology has created a skills gap

The demise of the National Diploma in Polymer Technology previously offered at erstwhile Technikons have resulted in a lack of valued and immediately employable technicians. This is bemoaned as having set the polymer (plastics) converting industry way back from where it should be due to a critical knowledge and skills gap in the industry that remains unfilled.

Engineers and technicians in the plastics industry:

Current employment status and trends

Specific Finding 9:

Engineers' current employment status is limited

The current employment status of engineers in the plastics industry is limited in terms of formally qualified personnel who are generally only employed by larger companies. For the most part, companies feel that formal engineers are not needed in the industry, especially those with low levels of specialisation. Furthermore, in smaller companies, engineering function and responsibility is often 'seamlessly' handled by a highly capable technical team.

However, there is an awareness that there may be a future need as there is a growing appreciation for the 'differential value-adding' between engineers and technicians.

Specific Finding 10:

Declining work opportunities for graduate Polymer Scientists

There are limited declining employment opportunities for Polymer Scientists. They are mainly employed by raw material suppliers and large master batch producers but technical and laboratory services at these enterprises have declined resulting in less work opportunities for graduate Polymer Scientists.

Specific Finding 11:

Difficulty recruiting suitably qualified and experienced personnel across all categories

There has been a decline over the years in a pool of manufacturing "industry ready" engineering graduates across the disciplines of electrical, mechanical and chemical. Overall there has been a drop in the success rate of hiring across engineers, technicians, technical manager and artisans.

Job title and function differentiation in relation to company size

Specific Finding 12:

Generally, but not exclusively, the scope of work increases as company size decreases

Whilst job titles may be the same across large and small companies, generally the scope of work is much broader as company size decreases. In small companies there is multi-job performance preferred over job specialisation and specialised expertise is contracted in when required. Conversely, in large companies, there is more scope and resources for employing specialist high level functionaries.

However, this is not hard and fast and one industry respondent felt that there was a need for multi-tasking and 'crossing boundaries' regardless of company size.

Appointment and Promotion Criteria

Specific Finding 13:

Appointment

Industry experience is considered more important than qualifications for production staff. In terms of higher level technical and management positions, in the past smaller companies appointed and promoted based on ability, whereas larger companies generally required qualifications. At a management and supervisory level, in-house development is strongly favoured compared to externally-recruited candidates.

Specific Finding 14:

Promotion

Internal promotion is preferred to external appointments and for senior and technical positions, an employment agency is used. Internal promotion is linked to in-house training based on performance monitoring and aptitude.

Other criteria noted by respondents in promotion assessment relate to personal attributes, for example, the 'mind-set' of employees and how they apply themselves in the workplace, reliability, accepting of responsibility, time-keeping, and communication and interpersonal *people skills – with particular reference to technically skilled staff being considered for promotion to supervisory or managerial positions.*

OFO Codes

Specific Finding 15:

<u>The OFO codes are considered too rigid and too limiting</u> in descriptors to adequately fit industry job titles. Industry also felt that the codes did not adequately address differences in performance and wage differentials as applied by companies in the workplace.

Applying the codes is considered a burdensome exercise done for the sake of compliance, because the codes are so generic that in many cases it becomes meaningless, as the codes lack industry sub-sector specificity.

However, in instances where Skills Development Facilitators (SDFs) are contracted to complete Grant applications to merSETA, no problems were reported, suggesting that 'interpretive understanding' on the part of SDFs removed the burden on industry to select appropriately aligned codes.

Knowledge, skill and attribute shortfall

Specific Finding 16:

- *Problem-solving (abstract) skills significantly lacking among engineering graduates*
- *Management skills*
- *Interpersonal and communication skills which undermines collaboration and team work capability*
- *Administrative skills*
- *'Right' attitudes*

Training provision shortcomings

Specific Finding 17:

<u>In general</u>

- *Industry-wide and industry–specific training is desperately needed*
- *The pervasive, entrenched and reactive culture of 'we'll make plan' undermines a systematic and industry needs-driven knowledge and skill development intervention in the long term*

<u>HE level (degree and diploma)</u>

Too few plastics industry-focused degrees and diploma offerings to cater for industry needs.

[NOTE: additional findings below]

<u>Intermediate level</u>

Systemic short-comings are decried with regard to artisan training and development for the plastics industry, with a particular lack of formal training opportunities in respect of:

- *blow moulding artisan development (compensated for by way of head-hunting/ poaching from opposition or in-house training)*
- *colour matching (a polymer scientist is too highly qualified to fulfil this function)*

In this regard, the demise of the apprenticeship system is bemoaned, as representing the 'ultimate' mode for knowledge transfer.

Supplier training

- *Supplier training by raw material suppliers, Sasol in particular, is found to be highly beneficial – the cessation of training or technical support by the distributors for Safripol and Plastimark is consequently bemoaned*
- *Overall, though, it is felt that there is 'too little' supplier training taking place. The perceived reason is attributed to technical knowledge limitations on the part of polymer sales people*

HE provision – education and training of technicians and engineers for the plastics industry and research foci and activities

Qualifications and Programmes

Undergraduate level

HE Institution	Department / School	Qualification	NQF level	Years
NELSON MANDELA University	CHEMISTRY	National Diploma in Polymer Technology	6	3
		Diploma in Analytical Chemistry	6	3
		Diploma in Chemical Process Technology	6	3
		Advanced Diploma in Analytical Chemistry	7	1
STELLENBOSCH University	CHEMISTRY and POLYMER SCIENCE [1]	BSc in Chemistry and Polymer Science	7	3
		BSc in Textile and Polymer Science [2]	7	3
TSHWANE University of Technology	CHEMICAL, METALLURGICAL and POLYMER Engineering	BTech in Polymer Technology → *To be phased out at end of 2019* *(See below for replacement program)*	7	1
		BEngTech: Materials Engineering in Polymer Technology → *Phase in 2020*	7	3

[1] The only Chemistry Department in the country that is officially designated as a Department of Chemistry AND Polymer Science

[2] In 2019/ 2020 to change to 'Materials Technology and Polymer Science'.

<table>
<tr><th>HE Institution</th><th>Department / School</th><th>Qualification</th><th>NQF level</th><th>Years</th></tr>
<tr><td rowspan="4">University of CAPE TOWN</td><td colspan="2">NOTE: Different under-graduate routes to Materials Engineering via mechanical <u>or</u> chemical engineering undergraduate programmes + linkage to materials engineering by way of elective courses in 3rd or 4th years (see below) – followed by opportunity for Materials Engineering specialisations at post-graduate level.</td><td></td><td></td></tr>
<tr><td>CHEMICAL Engineering</td><td>BSc (Eng) Chemical Engineering (*)
→ 4-year programme</td><td>8 *</td><td>4</td></tr>
<tr><td>MECHANICAL Engineering</td><td>BSc (Eng) Mechanical Engineering (*)
→ 4-year programme</td><td>8 *</td><td>4</td></tr>
<tr><td>Centre for MATERIALS Engineering (CME) [3]
(Located in the Mechanical Engineering Department)</td><td><u>Undergraduate Courses (Electives)</u>:
• materials science in engineering
• electrical and mechanical materials
• materials under stress
• manufacturing with materials
• materials science laboratory project
• metallic materials
• ceramic materials
• polymeric materials
• composite materials</td><td>(6-7)</td><td>1</td></tr>
<tr><td>University of PRETORIA</td><td>CHEMICAL Engineering
SARChI Chair in Carbon Technology and MATERIALS
DST Chair in Fluoro-MATERIALS Science and PROCESS Integration
→ Institute of APPLIED MATERIALS</td><td>NO undergraduate programmes aligned to materials (polymer) science / engineering</td><td></td><td></td></tr>
<tr><td>WITS University</td><td>CHEMICAL AND METALLURGICAL Engineering</td><td>BSc (Eng) in Chemical and Metallurgical Engineering **
(**) Polymer Science as a core subject</td><td>8</td><td>4</td></tr>
</table>

Post-graduate level

<table>
<tr><th>Institution</th><th>Department / School</th><th>Qualification / program</th><th>NQF Level</th></tr>
<tr><td rowspan="3">NELSON MANDELA University</td><td rowspan="3">Chemistry</td><td>BSc Hons (Chemistry)
[Polymer Chemistry as Elective Module]</td><td>8</td></tr>
<tr><td>MSc in Polymer Chemistry</td><td>9</td></tr>
<tr><td>PhD in Polymer Chemistry</td><td>10</td></tr>
</table>

[3] Prepares students for registration for research degrees in Materials Engineering at the Master's and ultimately Doctoral levels.

Institution	Department / School	Qualification / program	NQF Level
STELLENBOSCH University [4]	Department of CHEMISTRY **and** POLYMER Science [5]	BSc Honours in Polymer Science	8
		MSc in Polymer Science	9
		PhD in Polymer Science	10
TSHWANE University of Technology	Department of CHEMICAL, Metallurgical and POLYMER Engineering	BEngTech Hons (Polymer) → *Phase–in 2021*	8
		[M.Tech and D.Tech in Polymer Technology] → *Being phased out*	*9 & 10*
		MEng (Polymer) → *Phased–in 2017)*	9
		DEng (Polymer) → *Phased–in 2017*	10
University of CAPE TOWN	CHEMICAL Engineering Department	BSc (Honours) in Materials Science → *Aim: To provide one year of intensive training in Materials Science and Technology*	8
	MECHANICAL Engineering Department → *Centre for MATERIALS Engineering (CME)* [6]	MSc (Eng) in Materials Engineering	9
		PhD (Eng) in Materials Engineering	10
University of PRETORIA	Department of CHEMICAL Engineering *SARChI Chair in Carbon Technology and MATERIALS* *DST Chair in Fluoro-MATERIALS Science and PROCESS Integration* → *Institute of APPLIED MATERIALS*	BEngHons (Chemical Engineering) *Carbon, Fluorine & Polymer Materials* as specialisation* *(*) Core polymer-specific courses:* i) Product design, ii) Polymer materials science, iii) Polymer processing, and *iv)* Polymer additive technology	8
		BScHons (Applied Science)	8
		MEng (Chemical Engineering)	9
		DEng (Chemical Engineering)	10
WITS University	School of CHEMICAL and Metallurgical Engineering	PGDip (Eng) Programme → *Materials Science + Engineering as specialisation*	8
		MSc (Eng) Materials Science	9

[4] Stellenbosch University is the only university that officially offers a Polymer Science undergraduate stream.
[5] The only Chemistry Department in the country that is officially designated as a Department of Chemistry AND Polymer Science
[6] Prepares students for registration for research degrees in Materials Engineering at the Master's and ultimately Doctoral levels.

Institution	Department / School	Qualification / program	NQF Level
		PhD (Eng) Materials Science	10

NOTES:

1) New BEngTech in Materials Engineering in Polymer Technology for TUT (2020 phase-in).
2) Stellenbosch University is the only university that officially offers a Polymer Science undergraduate stream.
3) Adoption of UK Apprenticeship 'Degree' Model by WITS.
4) Honours programmes in Polymer/ Materials Science and Materials Engineering viewed as the 'ideal' option or vehicle for up-training of industry (technicians/ technologists).
5) TVET-HE articulation – no formal collaborative framework in place in regard to TVET colleges, so students who enter HE studies do so on the basis of meeting specific course entry requirements.

Short courses

HE Institution & Department / School	Courses
NELSON MANDELA UNIVERSITY *Chemistry Department*	A short course in Practical Rubber Technology appears to be the only polymer industry-related course currently on offer. [7]
STELLENBOSCH UNIVERSITY *Department of Chemistry* ***and*** *Polymer Science*	PAST Short courses (two- to three-day duration) were offered on an *ad-hoc and company-specific basis* (e.g. for Sasol employees). These courses varied in level and focus, from "introducing technical staff to the science of the projects that they are working" to "doing the more advanced courses for engineers and scientists – plant scientists in particular". PRESENT "No, but we want to". Short course provision is currently being (seriously) *re-considered* in response to requests from industry. The biggest *constraining factors* concern practical aspects like timing, contact time required, staffing and costing (return on investment) The thinking at this stage is to offer short courses as *modular units* which, if compiled or if put together and compiled as a unit, will it eventually *lead to the qualification of an Honour's degree*.
TSHWANE UNIVERSITY OF TECHNOLOGY *Department of Chemical, Metallurgical and Polymer Engineering*	Provision of industry-relevant short courses supported in principle BUT not doable at present due to issues of physical of human resources and funding. In response to requests from BTech students, a semester bridging subject as part of BTech (running concurrently) focusing on the basics of materials and

[7] Source: https://continuingeducation.mandela.ac.za/Other-Courses/

HE Institution & Department / School	Courses
	processing so as to offer students the opportunity to gain more background regarding materials science and processing.
UNIVERSITY OF CAPE TOWN *Chemical Engineering Department* → *Centre for Materials Engineering (CME)*	No current offerings.
UNIVERSITY OF PRETORIA *Department of CHEMICAL Engineering* *SARChI Chair in Carbon Technology and MATERIALS* *DST Chair in Fluoro-MATERIALS Science and PROCESS Integration* → *Institute of APPLIED MATERIALS*	PRESENT: Short courses for people from industry as primary target group not currently offered due to "industry funding having dried up". PAST These courses, at post-graduate level – usually one to three-days duration at a cost around R3,000/ day – focused on career-enhancing training in *product development, materials compounding and moulding processes* for *polymer materials* and *plastics components*. *Example* The short course in Polymer Processing and Plastics Product Development provides delegates with an *introduction to plastics as materials, including their development and compounding technology*. The numerous influences of *fillers* and filler–matrix interaction, as well the *machine and process design* are discussed in-depth with a focus on the *design of flame-retardant compounds, polymer modifications, testing and application*. This intensive three-day course is divided into three parts – each with the aim to logically improve delegates' knowledge about *plastics engineering*. The course also gives an overview of shaping processes, with a focus on injection moulding. In-depth process-related properties of plastics, special injection moulding technologies and process chains are also reviewed. *Learning Outcomes:* The objective of this course is to review aspects of the current state of the art in polymer compounding, plastics injection moulding and product engineering. On successful completion of the course, delegates will have the knowledge and understanding to place them in a position to deal with aspects of: • principles of polymer compounding and processing and their effects on morphological structure and properties of manufactured plastic products, and • material and process selection, product design for manufacture, plastics conversion techniques, especially injection moulding and in-mould plastics bonding *Course Content:* • Day 1: Compounding of multiphase plastics • Day 2: Shaping of plastics • Day 3: Processing and product development *Entry Requirements:* Some prior knowledge or experience in the field of *plastics conversion* or *engineering* is recommended.

<table>
<tr><th>HE Institution & Department / School</th><th>Courses</th></tr>
<tr><td></td><td>These courses were conducted by internationally-renowned (plastics) polymer industry experts, for example, Prof. Christian Bonten, head of the Institut für Kunststofftechnik (IKT) at the University of Stuttgart in 2010[8].

The expertise of the IKT comprises the entire field of plastics engineering: material engineering, processing technology and product engineering. Research concentrates on the interaction between material, process and product, in order to improve processability and part properties, intending to create innovative plastic products which are resource efficient and marketable.

Research examples:
• Material engineering: compounding new plastics as well as bioplastics
• Processing technology: innovative techniques and efficient machines
• Product engineering: new plastics products, metal substitution, non-destructive part testing</td></tr>
<tr><td>WITS UNIVERSITY
School of Chemical and Metallurgical Engineering</td><td>The Short Course Unit of Wits Enterprise is responsible for the administration of many Wits University short courses including courses offered to the public as well as short courses which are customised to meet the needs of specific stakeholders.

Short courses for the public by the School of Chemical and Metallurgical Engineering are offered at postgraduate level and are run at the same time as a post-graduate course. They are open to anyone who has an interest in that area (industry participants specifically); that is, there are no pre-requisites and they attend at the same time as the postgraduate students do. Advertising occurs by way of putting it on the Wits Enterprise website.

The participants from industry get a certificate of attendance at the course while the students get additional reading material that they have to work through, write an examination on it and they also have to submit an assignment or a project towards a qualification.

Attendance runs over a (block) week, from eight o'clock until five o'clock every day. Participants attend lectures and get do various exercises and calculations and are taken on a plant visit one day during the week.

Short course provision 2019:

➢ <u>Materials Characterisation (NQF Level 9)</u>
Aims of the course:
The aim of the course is to introduce students to different characterisation techniques that can be critically used to understand material behaviour, failure analysis, and corrosion mechanisms.
Duration: 10–14 June 2019
Cost: R9,900 (TBC)
Course Content
Materials selected from the following categories: metals, insulators and semiconductors, Polymers and Polymer Composites, Ceramics and ones with interesting surface properties, such as Catalysts. Information needed to characterise each material will be identified and the type of physical interactions needed to obtain this information discussed. The details of the relevant technique will then be given, such as electron microscopy, Raman</td></tr>
</table>

[8] Source: www.uni-stuttgart.de/en/press/experts/Prof.-Dr.-Christian-Bonten

HE Institution & Department / School	Courses
	Scattering, Nuclear Magnetic Resonance, Mass Spectroscopy, Rutherford Backscattering. *Learning Outcomes:* i) Gain an understanding and overview of basic principles of popular materials characterisation techniques and their limitations. ii) Use the skills learned to apply different characterisation techniques in important engineering practices.

Research

Table 5: Plastics industry-aligned RESEARCH activity and focus areas

Institution & Department / School	Research foci and activities
NELSON MANDELA University *Department of CHEMISTRY*	The Chemistry Department offers postgraduate programmes at Masters (MSc) and Doctorate (PhD) levels in Chemistry. Research in the Department is focused on the following areas: • battery chemistry • POLYMER chemistry • solid state transitions metal ion separation • nanomaterials analytical chemistry • microalgae technologies catalysis • natural products chemistry fuel chemistry • supramolecular chemistry bioinorganic chemistry Research Chair: Professor Paul Watts *Microfluidic Biochemical Processing* Professor Watts' research aim is to develop a *continuous flow methodology* to investigate how small production platforms can enhance chemical manufacture within the South African economy. In addition, research will be undertaken to investigate the integration of synthesis and purification within continuous flow systems.
STELLENBOSCH University [9] *Department of CHEMISTRY AND POLYMER Science* [10]	Fundamental research with practical application – i.e. 'analytical and problem-solving service' to industry The MSc and PhD degree programmes are at the heart of the department's research activities. Students enrolled for these advanced research degrees are required to complete an original research project and thesis in any one of the ***research groups*** of the Department of Chemistry and Polymer Science. These are: 1) Functional polymers, polymer-protein conjugates, functional and dynamic hydrogels *Research leader*: BERT KLUMPERMAN, distinguished Professor of Polymer Science

[9] Stellenbosch University is the only university that officially offers a Polymer Science undergraduate stream.
[10] The only Chemistry Department in the country that is officially designated as a Department of Chemistry AND Polymer Science

Institution & Department / School	Research foci and activities
	Research fields: Polymer chemistry, reversible deactivation radical polymerization, post-polymerization modification, analytical chemistry 2) Advanced analytical polymer science, multidimensional chromatography *Research leader*: HARALD PASCH, distinguished professor of polymer science *Research fields:* (polymer science /analytical chemistry) • Polymer structure elucidation for structure-property correlations • Comprehensive analysis of industrial polymers • Polymer reaction control and monitoring 3) Polymer structure-property relationship, polymer hybrid materials, polymer nanocomposites and nanofibers *Research leader:* PETER MALLON, Professor of Polymer Science *Research Fields:* Polymer science, solid-state morphology of complex polymers, polymer nanocomposites and polymer nanofibers 4) Structure–property relationships (polymers) *Research leader:* ALBERT VAN REENEN, Professor of Polymer Science *Research Fields:* Prof van Reenen does a lot of work in structure–property relationships and for the last two decades developed strong partnerships with local industry and specifically Sasol and Safripol, the large polymer producers. His more recent focus is on packaging and food security – smart packaging systems, which he views as “the next big thing”.
TSHWANE University of Technology *Department of Chemical, Metallurgical and POLYMER Engineering*	No data obtained
University of CAPE TOWN *CHEMICAL Engineering Department*	The CHEMICAL Engineering Department's research activities are at present centred on: • biological leaching of mineral ores • bioprocess engineering • catalysis • crystallization and precipitation • environmental process engineering, • hydrogen and fuel cell technologies • hydrometallurgy for metal extraction • minerals processing • process modelling and optimization • process synthesis • value recovery from waste, • water remediation, treatment, recovery and foot-printing
MECHANICAL Engineering Department	The Doctoral programme is research (thesis)-based in respect of the following focus areas: • Mechanical Engineering • Engineering Management • Sustainable Energy Engineering • MATERIALS Engineering *

Institution & Department / School	Research foci and activities
Centre for Materials Engineering (CME) [11]	• Energy & Development Studies • Engineering Education *(* Through the Centre for Materials Engineering (CME) located in and in close association with the Department of Mechanical Engineering.)* UCT Centre for Materials Engineering[12] *Collaborative Research* The Centre interacts with local industry on various levels to provide solutions related to materials selection, manufacturing and processing, materials specification, and component failure analysis. The well maintained laboratory infrastructure and in-house expertise enables a comprehensive consultancy service to be offered to industry, where use can be made of a wide range of test and analytical techniques. The Centre is particularly interested in assisting the manufacturing industry and is able to coordinate projects that may involve several aspects of manufacturing, through interaction with related groups in the Faculty of Engineering and the Built Environment at UCT
University of PRETORIA *Department of CHEMICAL Engineering*	Research focus "very general" but in regard to POLYMERS it's about *modifying polymers with additives and using polymers as active release, i.e. controlled release systems*. Correspondingly, the focus of research activities span stabilizers, heat stabilizers, pro-degradants, corrosion inhibitors, flame retardants, repellents, and insecticides.
WITS University *School of Chemical and Metallurgical Engineering*	SCOPE AND FOCUS Research is concentrated in these fields and although a strong theoretical tradition is retained, practical research is encouraged. Close liaison is maintained with the *Chemical and Mining industries* and all means of increasing such contacts are continually being explored. Minerals process engineering enjoys a particularly strong emphasis in this respect. Currently *NO plastics (polymer) industry-aligned research activity* occurs as "Polymers is the Cinderella in our School" (Head of School) RESEARCH SUPPORT The *Wits Enterprise's Research Support Unit* acts as an "easily accessible one-stop channel that links the University of the Witwatersrand's (Wits) academics / researchers with the external social and economic world – it helps them source and manage research and consulting services, so as to while ensure adherence to relevant University policies and Government legislations, mitigating risk and increasing efficiency.

[11] Prepares students for registration for research degrees in Materials Engineering at the Master's and ultimately Doctoral levels.
[12] CONTACT DETAILS: Centre for Materials Engineering, University of Cape Town, Private Bag, Rondebosch 7701. Tel +27 21 6503173 | Fax +27 21 6897571 | Email sarah.george@uct.ac.za (Source: www.mateng.uct.ac.za)

Views of HE respondents on the education and training of engineers

Specific Finding 18:

Core purpose and focus of higher level [HE] education and training is about principled learning and imparting high level analytical skills

Specific Finding 19:

Value-adding "generic attributes" of graduates (Masters and Doctoral graduates in particular) are mis-understood and therefore not sufficiently appreciated by industry

Specific Finding 20:

Ideal plastics industry engineer (qualification mix) – a process engineer with a post-graduate qualification (either Honours degree or Post-Graduate Diploma) in (plastics) polymer science'.

Specific Finding 21:

Lack of/ significant shortfalls in funding is the single-most critical factor impeding teaching and research outputs

Industry respondents' views on HE provision for engineers

Specific Finding 22:

Link between science and the mechanical side missing

Whilst graduates have learned the polymer science and design aspect, they lack the mechanical knowledge to complement their theoretical knowledge. A holistic understanding of the entire production process is needed.

Specific Finding 23:

"Expensive degree" if graduate has no relevant plastics industry exposure

The lack of real world of work experience and understanding from graduates is of deep concern to industry, as it involves long periods of familiarisation on company time and at company cost and they still stand the risk of losing the person afterwards when they are 'marketable'.

Specific Finding 24:

Graduate conceptual thinking compensates

Conceptual thinking ability of graduates compensate for initial lack of operational / practical and process knowledge, with particular reference to problem solving abilities and understanding of the principles behind operations.

Specific Finding 25:

Graduate lack of awareness of the business environment.

Specific Finding 26:

Unrealistic attitudes and expectations

Newly graduated engineers have unrealistic expectations about their job function, competence, earning capabilities and promotion prospects as well as an aversion to internship-based shop floor exposure and learning due to an 'uppity' attitude.

Specific Finding 27:

"Ideal" qualification / knowledge blend for graduates in the plastics conversion industry

- A combination of mechanical engineering and polymer science due to the plastics converting industry having a strong engineering function dominated by machinery
- "Turnkey (polymer) scientist", i.e. fully work-ready polymer scientists familiar with machinery and equipment

Status of Industry–Higher Education collaboration

Views of Industry Respondents

Specific Finding 28:

a) Little / lack of collaboration on the part of Higher Education

b) Formal channels for engaging with Higher Education institutions lacking

c) Intellectual property rights issues regarding collaborative research outputs

d) Industry-specific training and research institutes are largely lacking in South Africa

Views of HE respondents

Specific Finding 29:

a) Industrial Advisory Boards as primary formal structure for engagement with industry

b) Close historical relationships by virtue of having been "born of" industry

c) Ad hoc troubleshooting service as the basis for engagement

d) Strong advocacy amongst stakeholders regarding collaboration BUT no substantive action accompanies engagement

e) Partnerships developed and sustained on the basis of trust relationships between key individuals

Suggestions to strengthen industry and the supply of engineers and technicians in particular

Views of Industry Respondents

Specific Finding 30:

a) Industry-wide and specific training desperately needed

b) Adopt the German Model

c) *Reinstate a plastics technology diploma*

d) *Combine initial Higher Education and Internship-based training*

e) *Workplace exposure for students instead of full internship*

f) *Higher Education curriculum development and alignment in consultation with industry and informed by research*

g) *Establishing a highly-visible, multi-sectoral and multi-level skills planning and development pipeline involving all stakeholders and role players*

h) *Higher Education institutions to acquire machinery*

i) *Through Plastics Chamber–HE collaboration develop a broad spectrum and pool of skills catering for the multiple skills needed by all the plastics industry sub-sectors*

j) *Plastics SA Training – PSA the 'obvious' training partner to industry*

k) *Provincial specialist training centres required*

l) *Industry as a whole should support TVET colleges more proactively on an interactive partnership basis*

m) *As the major raw materials supplier, SASOL should be funding internships.*

n) *Advocacy for careers in plastics industry*

o) *Plastics Chamber—Higher Education collaboration*

p) *Optimising monitoring and development research focus*

q) *Collaborative research around key plastics engineering problems/challenges*

r) *Optimising the use of university department's equipment and post graduate student resources to solve industry research and development challenges is seen as an opportunity*

s) *Providing a forum, on a regular basis, where universities and students can inform industry about their research focus areas and potential benefits to be derived by industry is viewed as beneficial*

t) *'Good' practices promoting company well-being*

- *'International-level' in-house training*
- *Implementing the Mission-Directed Work Team Concept*
- *Extensive induction*
- *'Active' data monitoring and analysis in support of productivity and processing optimisation*
- *Exposing staff to polymer science basics*
-

Views of Industry Association Respondents

Specific Finding 32:

a) *The relationship between industry and higher education is not a simple one and in some instances it is viewed as 'adversarial'.*

b) *Manufacturing exposure*

c) *Importance of standards and testing as a key focus area for consideration – to implement and uphold standards in the industry.*

d) *Applied research*

Views of HE Respondents

Specific Finding 33:

a) *Two-stream model for post-graduate provision – a Masters and Doctoral stream but also allowing for exit at Honours Level*

b) *Three-tiered approach to education and training for plastics industry-focused graduates*

- *Level 1: Focus on producing Technicians and Technologists (BTech)*
- *Level 2: Honour's level focus targeting 'people knowing chemistry or chemical engineering, but who don't know plastics'.*
- *Level 3: Focused at Masters and PhD levels where students conceptualise projects and test for workability in the laboratory, after which they are employed by industry to develop these projects and processes (up-scale) for eventual commercialisation.*

c) *Internships – as representing "the only" vehicle for facilitating industry-readiness of (post- graduates) 'at no cost to company' (however, lack of interest from companies is bemoaned)*

d) *Establish plastics industry RESEARCH CHAIR – as most effective and cost-effective model for stimulating / driving effective and cost-effective innovation research in the plastics (polymer) industry*

Overall Findings

(Graduate) engineers and technicians in the plastics industry

Overall Finding 1:

With regard to the actual current uptake level of graduate engineers and post-graduates in polymer/ materials science or materials engineering (Masters or Doctoral level), these functionaries are generally not perceived to be 'specifically needed' or deemed essential for company or plant functioning and performance.

However, there is evidence of an increasing awareness and appreciation of engineer–technician differentiation in relation to roles or job functions and corresponding value-adding, in respect of principled knowledge and high-level analytical capabilities of engineers in particular.

Overall Finding 2:

Apart from sub sector-specific shortcomings with regard to practical knowledge and expertise (a 'logistical' issue preventing on-course practical exposure to current industry machinery), reported areas of knowledge and skill/competence and attribute shortfall or underdevelopment among job entry-level graduate engineers (and polymer scientists) centre on high level analysis and advanced problem solving; contextual process/project management, interpersonal and communication skills, which undermine teamwork capability. Interestingly, shortcomings with regard to disciplinary knowledge were not highlighted.

Analysis of the stated learning outcomes and topical coverage in the relevant undergraduate curricula substantiates a finding that the identified areas of competence and attribute shortcomings are indeed covered in the curricula and therefore represent a curriculum 'uptake' issue (lack of transformative impact) rather than a curriculum 'shortfall' issue. This could be attributed to a number of possible factors, for example, students' shortcomings in regard to core learning-supporting aptitudes and attributes as well as motivation or commitment to studies ('complimentary' courses in particular) due to selection (and placement) processes-related issues, lack of early activation and awareness of the plastic conversion and materials industry in HE programmes, and integrated human capital development interventions.

HE education and training provision for the plastics industry

- ***Scope and relevance to the (plastics) polymer industry of current undergraduate and post-graduate qualifications and programmes***

Overall Finding 3:

Undergraduate provision is essentially limited to a BEng or BScEng degree in chemical engineering (four-year programmes), represent the 'stock and trade' entry-level programmes – with polymer industry-relevance linkage effected (to the extent that it does occur) by way of student exposure to materials science and processing as core or elective course modules. (Stellenbosch University the only HE institution offering a dedicated under-graduate qualification in polymer science.)

Ultimately, then, specialisation in polymer / materials science and materials engineering/ processing only occurs at the level of post-graduate studies. Whilst honours and/ or post-graduate diploma students are encouraged to pursue (research-based) masters and doctoral level studies, HE respondents share the view that these honours level graduates are ideally equipped for entering industry as well as starting their own entrepreneurial concerns.

Conversely, these self-same honours or post-graduate diploma offerings are also feted as representing the ideal vehicle for upskilling industry personnel who hold a national diploma and BTech in polymer technology specifically. However, the proviso is that enrolment is made possible on a part-time study basis and contact time takes place on a block attendance basis to limit absence from work.

In all, then, a 'materials science and engineering bias' would appear to, by and large, characterise the dominant disciplinary flavour in current HE programme offerings and research activity in relation to the polymer industry – that is, not also incorporating a mechanical engineering-linked conversion focus.

- ***An 'ideal' plastics industry-dedicated engineering qualification***

Overall Finding 4:

A graduate-level qualification combining polymer science and mechanical engineering disciplinary knowledge fields together with grounding in conversion sub sector-specific process knowledge is perceived by industry respondents as the IDEAL for the education and training of engineers for the plastics (conversion) industry.

By contrast, HE respondents' views favour a qualification comprising a polymer/ materials science–process (chemical) engineering disciplinary blend focused on providing students with a solid grounding in knowledge of 'plastics-specific' science and processing.

- ***Funding shortfall as critical cross-cutting theme impacting on education and training provision and uptake as well as research output***

Overall finding 5:

Increasing 'critical' shortfalls in funding for universities in recent years severely inhibit the capacity of academic departments and research institutes to deliver on all aspects of provision. This is evidenced in a significant decline in post-graduate student enrolment and, consequently, research activity and outputs, demand for research collaboration and short courses. A reported ''drying up' of funding by industry is bemoaned in particular.

Particularly noteworthy are the following funding-related shortfalls and implications:

- *Obtaining bursary funding for both undergraduate and post-graduate students has become increasingly difficult in recent years – that is, not just for covering tuition fees but also living and travel expenses.*
- *Research funding in respect of post-graduate student enrolment and research projects (Masters and Doctoral level), bearing in mind universities do not receive any government funding for research purposes. Consequently, all research projects have to be self-financed by departments/ institutes, which includes bursaries for the post-graduate students, funding for their research projects (anything between R400k to R600k), purchasing and maintenance of research equipment, as well as equipment required for practical training.*
- *Funding for internships for graduates. Funding (from whichever source) of internships for newly-qualified engineers by and large is 'not happening', which holds critical implications for 'growing' sub-sector specific expertise and experience.*
- *Industry demand or support (sending delegates) for short course provision has declined dramatically in recent years with a corresponding decline in offerings as*

'minimum' attendance requirements for ensuring presentation cost recovery (including staff contracting) cannot be met. Whilst the ongoing depressed economic climate is fingered as the main contributing factor, part-blame is also laid at the doors of industry bodies with regard to insufficient advocacy for, and facilitation of, industry participation.

HE–Industry partnerships and collaboration – shortcomings

Overall Finding 6:

By respondent accounts it would generally appear that a 'disconnect' characterises the status of industry—HE relations, and, by extension, partnership-driven engagement and collaboration. This is in contrast to some instances of long-established relationships and ongoing cooperation. As consequence, a significant degree of ignorance, if not mis-understanding, concerning the 'other' constituency's offerings and support needs is in evidence, which ultimately results in foreclosure on opportunities for collaboration.

Various strategies and interventions have in the past been adopted for establishing or opening up channels or forums for engagement, but these appear to have either failed outright or lacked sustainability in the course of time; leaving informal networking by individuals as the quintessential mode of engagement, to the extent that it actually happens.

This has negatively impacted both industry and HE in different ways and has hindered growth and performance of the sector. It is somewhat ironic as both constituencies appreciate their mutual interdependencies but they cannot seem to establish a long-term sustainable collaborative framework that addresses the needs for; relevant research, materials science development, industrialisation of research output, testing facilities and the support needed for standardisation of processes and products.

Overall Finding 7:

A general lack of an established culture close, trust-based 'working relationship' between industry and HE institutions inhibits the development and commercialisation of innovative research concepts by HE institutions on a collaborative basis, with industry appearing to be the reluctant partner by and large – in contrast, that is, to the more established ethos of industry approaching HE research institutions with research request or briefs, usually for materials characterisation and development, and/ or product testing as well as any other research or analysis-based trouble shooting.

Overall Recommendations

Stimulating the uptake of engineers in the plastics industry

> ***Overall Recommendation 1:***
>
> *The current low uptake of qualified engineers (at graduate and post-graduate levels) in industry – perceived to stem from a lack of awareness or misunderstanding about their value-adding capability, and lack of sub-sector-specific knowledge and skill – could (in-part) be mitigated through advocacy by industry bodies. The advocacy role would mitigate the lack of awareness and highlight the potential value add of qualified engineers with regard to company functioning and performance by way of the engineers 'generic' value-adding attributes – principled disciplinary knowledge, social and economic understanding of the impact of engineering activities, high-level analytical capability and (associated) capacity for critical and innovative thinking.*

Enhancing relevance to the plastics industry of HE provision with regard to the education and training of engineers

> ***Overall Recommendation 2:***
>
> *Current HE provision with regard to the education and training of plastics industry-focused engineers could be strengthened by way of the following interventions:*
>
> *Plastics industry bodies raising awareness and advocating uptake in respect of education and training opportunities at relevant HE institutions.*
>
> *Amending the current 'stock and trade' qualification (at honours/ post-graduate diploma level) comprising a polymer/ material science—process/ materials engineering disciplinary mix to also include a mechanical engineering dimension whilst also reducing the scope of the polymer science component to an exclusive 'plastics knowledge' focus in consultation with ECSA.*
>
> *Such an undertaking should take the form of a joint venture between the relevant HE institutions and industry stakeholders, with funding, as may be required, provided by industry.*

> ***Overall Recommendation 3:***
>
> *Enhance world-of work readiness or 'familiarity' of engineering and polymer science graduates by improving the quality and relevance of appropriately equipped practical training facilities at HE institution,s in partnership with industry and funding provided by the latter – as well as implementing early industry awareness and activation with undergraduate learners about the opportunities in the plastics industry*

Strengthening Industry-HE relations and collaboration

> ***Overall Recommendation 4:***
>
> *Against the background of the disconnect characterising Industry—HE relations and engagement as well as unsuccessful attempts in the past to establish effective and sustainable modes or mechanisms for engagement and collaboration, industry bodies – Plastics Chamber and Plastics SA in particular – should take the initiative in devising effective ways of engagement that would ensure partnership development and collaboration around mutually-shared concerns, needs and aspirations with the ultimate goal of high-level human capital development for growing an innovative and competitive plastics industry.*

Sector strengthening through engineering qualifications 'alignment' and substantial funding of industry-relevant HE research activity

> ***Overall Recommendation 5:***
>
> *In view of the 'insufficiently plastics-focused' shortcomings of current HE qualifications and programmes governing the education and training of engineers for the industry, it is suggested that the Plastics Chamber and Plastics SA assume strong leadership and facilitating roles to effect changes in regard to current provision suggested by industry and HE, in pursuit of developing the 'qualification of ideal disciplinary mix' for ensuring the supply of dedicated plastics industry engineers and scientists.*
>
> *Conversely, these industry bodies are implored to find creative and substantial ways of alleviating the increasing funding crisis burdening HE institutions, with particular reference to diminishing student uptake at post-graduate levels and a corresponding decline in research activity and output. Efforts to increase the declining uptake of short course provision by industry will go some way to developing a more trusted relationship between HE and industry, as mentioned above. Stimulating multi-dimensional industry funding-related investment and support in these regards should be the first and most critical priority.*

Introduction

The last research study by the Plastics Chamber (Garisch, 2016) comprised a study of innovation culture and capability in the plastics sector. The research followed a three-phased research initiative (Vorwerk, 2011; Vorwerk and Farquharson 2012/13 and Vorwerk and Farquharson 2014) which focused on:

- Industry value chains and the mapping of jobs against the Organising Framework for Occupations
- Understanding the size, shape and dynamics of the industry with respect to skills growth scenarios
- How best to attract, develop and retain technical talent

Garisch's (2016) study explored innovative practices in the plastics sector within a global context and sought to understand skills and knowledge required to support innovation in the context of a "futures orientation linked to advanced manufacturing". Garisch's findings, after extensive and broad industry consultation, was that there is a lack of systematic research and development-based innovation and that proprietary product innovation is only 30%. This results in an industry sentiment that it is "hard to survive and thrive" and where improved product response time is perceived as the competitive edge. Systemic issues such as government red tape, failure of the South African Bureau of Standards (SABS) and difficulties getting raw materials at the right cost were cited as further hinderances to being competitive in the plastics industry. From a skills and knowledge perspective, the industry felt that fewer young people are entering the sector and that there is a lack of a "skilful" pool of people to draw on.

Taking a closer look at skills requirements with respect to supporting a more innovative culture, the respondents felt that there was a plastics technician shortfall particularly with respect to mould making, machine technology and materials science. Operator fault finding and problem solving was highlighted as well as the need for industry specific skills and improved supervision capabilities.

The recommendations emanating from the study were:

- The implementation of an industry strategy inclusive of the whole supply chain and the integration of waste and recycling, including ongoing monitoring and evaluation
- Funded and employer-led training resulting in a "pool" of trained people to draw on
- 'More' and 'better' radical innovation

Based on the recommendations and within the context of a global focus on Industry 4.0 and the Circular Economy, the Chamber task team in June 2017, proposed an innovation research intervention comprising:

- A Plastics SA-strengthened innovation forum
- Partnerships with universities to close the gap between research and industry application
- Skilling people for innovation

The scope of the proposed study was acknowledged as being beyond the brief and remit of the Chamber Research project and could possibly be considered under an Innovation Grant Project. It was suggested at the November 2017 Chamber meeting that the focus be narrowed to understand university provision and to identify gaps as identified by industry. The study should make recommendations to the merSETA on future interventions that would support emerging areas of competence in the plastics sector.

In reviewing some of the respondent interviews conducted by Garisch (2016), there was supporting evidence from interview transcripts, that there was a level of "disconnect" between University provision and industry requirements.

> "I know universities also focus on industrial applications, but they don't usually get that right."
>
> "If you look at the university student that has studied in the Chemistry department, polymer specifically, then he cannot walk into a company and say, oh you know, let's make nanocomposites or some other and then they just do it. It doesn't work like that. So that skill is also lacking in industry."
>
> "They have doctorate students and the problem is now with the funding that is cut at universities… they don't actually have the money to support these guys research anymore, so now they are looking for something that they can sell as well"
>
> "… whether those lecturers that you're actually going to are current enough in thinking and are they orthodox enough, are they actually teaching you current practices? Or are they so technophobic… they are resistant to change….. So yes, it comes back to the thinkers, because innovation is so key, but with that lecturer it's the same problem of repeating what his generation taught in comparison with the more kind of active institutions that are trying to teach some of this kind of methodology."

In a short literature review, a recent study by Chimpololo (2017) into technical skills gaps in the manufacturing industry in Malawi, partly focused on the plastics and packing sector. Chimpololo (2017: 15) found that at the technician level, 83% of respondents said there is a "shortfall of plastic products designers, plastics packaging technicians, electrical engineering technicians and mechanical engineering technicians who can maintain modern technology machines while 50% bemoaned a lack of laboratory technicians with knowledge in plastics technology." This mirrors, and supports, Garisch's finding and leads to the focus area of this research project proposal.

1. Research focus, design and methodology

1.1 Focus

In light of the shortage of technicians and the lack of preparedness of graduate engineers entering the workplace, the focus of this research will be on education and training provision for the plastics sector at University and University of Technology level. The artisanal and semi-skilled training needs of the plastics sector appear to be better researched and understood and steps are slowly being taken to address the shortfalls and develop new qualifications. The NQF levels 6–10 in the Higher Education band will be the core focus area of the study to understand what diploma, degree and post graduate courses are in place and whether they meet the specialised skills required by the plastics industry.

1.2 Design and methodology

1.2.1 Design

Problem statement and research questions

According to Plastics SA, “specialist engineers (beyond first degree) are reportedly not produced in a quantity that is sufficient for the growth of the plastics industry”[13].

This is supported by a study by Simon Roberts into Smart Industries and the importance of technology and R&D for industry performance[14]. Roberts looked at the plastics industry and identified two distinct classes of workers where skills scarcities are reported, being trained engineers and artisans (p. 82). He also identifies the weak relationships between industries, tertiary institutions, science councils and other research organisations (p. 87).

Roberts goes on to report; “There appears to be a gap between the supply of available research capacity and demand for that research capacity by certain industries such as plastic products. Given the importance of such linkages the author suggests the following action areas should be considered (p. 88):

- An assessment of awareness of relevant research institutions and centres
- Identify reasons for the lack of awareness and utilisation of policy initiatives
- Further identify available industrial research capacity and its location/ connectivity to industries
- Identify impediments to research collaboration across institutions

In light of the problem statement and findings to date, the overall purpose of the research is to establish the shortage of plastics technicians and plastics engineers in South Africa and to establish what can be done to address the problem.

1. The research is framed by the following ***key questions***:
2. What is the current Higher Education provision status with regard to technicians and engineers in the plastics sector in South Africa?
3. What specialised skills are required in the plastics industry?
4. Is there a shortfall or lack of education provision and, if so, what needs to be done to address the problem?

In view of the research remit for an in-depth exploration of the skills and knowledge needs linked to innovative practices in order to grow the plastics industry sector in South Africa, a predominantly qualitative research approach was decided on as best fit, with semi-structured interviews or “conversations with purpose” as the preferred data collection method.

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[13] www.plasticsinfo.co.za/training-2/; accessed 30/03/18 at 13h15

[14] www.Tips.Org.Za/Files/Smart_Industries_The_Importance_Of_Technology_And_Rd_For_Industry_Performance.Pdf (accessed 30/03/18 at 14h00).

1.2.2 Data collection and analysis

Data collection

In view of the research topic a mixed methods research approach utilising both quantitative and qualitative methods was decided on. Correspondingly, the data collection methods comprised semi-structured interviews, desk-top research and documentary analysis.

During the first phase, a preliminary literature review informed the conceptualisation of the investigative and analytical frameworks. These in turn informed the design of the interview instruments which were verified by the Plastics Chamber Task Team (Appendix 1).

Data collection involved three distinct phases:

Quantitative data

1) Analysis of the merSETA Workplace Skills Plan and Annual Training Report data for the last five years to track the number of people employed as technicians and engineers in the plastics industry. This part of the research was initially intended to provide a baseline picture of the number and demographics of technicians and engineers employed and to identify trends or patterns in job retention, contraction or growth. This data proved to be of limited use as a baseline picture for a number of reasons that will be discussed in the section on Industry employment data and OFO codes.

2) Desktop research of the universities/universities of technology forming part of the study sample (see description below) to document education and training provision (at NQF levels 6-10) aligned to/supporting technician and engineering employment in the plastics sector.

Qualitative data

3) Semi-structured (face-to-face) interviews were conducted across four categories of respondents so as to solicit views on key aspects concerning skills supply and demand in the plastics industry – in relation to technicians and engineers as well as specialised skills in particular:

    i) Engineering department / school heads and learning programme convenors at HE institutions (sample)

    ii) HR and Production Managers in a selection of plastics companies representative of the various sub-sectors of the industry

    iii) Newly-employed graduates in the plastics industry

    iv) Representatives of industry associations

    The semi-structured interview questionnaires (Appendix 1) were sent to participants ahead of the scheduled interviews and participants were encouraged to share their experiences and thoughts beyond the confines of the questionnaire template. A background to the research project was given before the start of the interviews and all interviews were recorded and transcribed verbatim. On average each interview was anticipated to take sixty minutes, but in some cases the interviews were longer and sometimes shorter depending on the level and scope of contribution. The conflation of engineer–technician–artisan regarding training, knowledge and skills emerged as a significant factor in the industry interviews, particularly with more junior or less experienced interviewees.

Data analysis

Qualitative data analysis is the process of moving from data (primary or secondary) to evidence-based interpretations and, eventually, to findings. The challenge of qualitative data analysis is enormous – to make meaning of usually large volumes of data and then to communicate the essence of what the data reveals in a clear and unambiguous manner.

The process of qualitative data analysis to reach findings represents an onerous task that involves iterative steps from primary data to evidence-based interpretations and eventually to findings. The aim of rigorous analysis of large data sets, as in this study, is to reach clear fact-based findings despite the sheer size and variety contained in the empirical data.

The first step in the analysis was “coding”. This involves firstly allocating a summative phrase, sentence or word for data portions or segments in the interview transcripts to adequately capture the data’s primary content/meaning. This first cycle of coding is closely linked to the key research questions of the study. The second cycle of coding further filtered and highlighted aspects of the qualitative data. In this process categories, themes and concepts emerge from the data itself. In some instances, the codes are broken down in further sub-segments to give a more nuanced and detailed representation of the data. Natural and deliberate patterns emerge from the coding activity to eventually explicate the key findings of the study along a thematic basis.

1.2.3 Sample description

Based on desk top research, the Universities and Universities of Technology were selected based on their *direct offering of plastics-related learning programmes* or *affiliated degrees*.

The selection of Industry Associations was based on a recommended initial list provided by Plastics SA. However, after telephonic engagement two industry associations felt that they did not have sufficient expertise in the area of technician and engineering training and both felt that there was a limited requirement for this higher level skill within the sub-sector industries that they represent. One association circulated a shortened questionnaire (based on the semi-structured interview instrument) to members for inputs, but nothing was forthcoming, suggesting limited engagement or need from the particular sub-sectors they represented. Three out of the targeted five industry associations participated in the research and a total of three interviews were conducted.

The selection of HR Managers, Production Managers and newly employed graduates from industry was informed by an initial informal interview with the editor of an industry magazine, based on recommendations from Plastics SA. After the interview and understanding the objectives of the study, the editor recommended a list of 27 companies representing the following sub sectors: Flexibles (film manufacture, printing and bag making), Blow moulding (bottles and containers), Injection moulding (technical moulding), Rotational moulding and Pipe extruders. From this list, 10 companies were selected with a regional spread reflective of the broad geographic spread of the industry, as well as being representative of the sub-sectors: Gauteng 4 companies, Western Cape 3 companies, Kwazulu Natal 2 companies, Eastern Cape 1 company.

merSETA-endorsed Letters of Invitation to participate in the research (please see Appendix 2) were emailed to all targeted companies, associations, universities of technology and universities and the researchers followed up by telephonic and electronic means. Securing participation of Higher Education institutions proved relatively easy, and one could surmise this is because of a shared understanding or appreciation of research activities. As discussed above, the response from industry association representatives was mixed and an alternate method of soliciting information had to be attempted but with limited success. Securing the participation of companies was more difficult, despite repeated attempts at electronic and telephonic follow up. Challenges experienced in this regard included the following: one company at the time underwent structural business changes (multi-national acquisition) which made access finalisation challenging; (two) companies reneging on initial pledges to participate 'for no reason', but only after an extended time lapse; a death in the family of a founding member at one company; and a prolonged strike at another.

Ultimately, such last-minute pulling out of participation meant that there was insufficient time left to approach alternative companies. In view of the consequent company sample shortfall, a compensatory measure decided on was to screen transcripts of the 2016 interviews conducted by Garisch (2016) and select those of relevance with regard to topical coverage and richness of data in relation to the research focus. It was felt that this empirical data supplementation measure did not represent an impediment to the study in any way.

In the end, seven companies out of the targeted 10 companies participated in the research, and a total of 18 interviews were conducted. The shortfall of three companies, as mentioned earlier, was supplemented by the 2016 research data (Garisch, 2016). The sub sectors represented by the 2016 company sample included: injection moulding, flexibles, blow moulding, masterbatch, packaging and cabling.

All six Higher Education institutions out of the targeted six participated in the study, comprising five universities and one university of technology. In all, nine respondents were involved – eight of which participated in interviews whilst in the case of one university the representative submitted written inputs via email as the scheduled interview had to be cancelled at the last moment due to unforeseen work commitments on the respondent's part.

Table 1: Geographical spread of interview participants

Provincial distribution	Total
Gauteng	27
KwaZulu-Natal	3
Eastern Cape	5
Western Cape	6
TOTAL	41

Table 2: Job titles of interview participants

Designation	Number
CEO	1
Development officer	1
Development specialist	1
Director	4
General manager (production)	1
HR Administrator	1
HR manager	4
Lecturer	2
Maintenance artisan	1
Managing Member	1
Manufacturing manager	2
Millwright	1
Polymer scientist	1
Polymer technologist	1
Process engineer	1
Process project engineer	1
Project Manager	1
Production manager	1
Professor	1
Professor & Departmental Head	1
Professor & Head of Institute	1
QA manager	1
QC manager	1
Representative	1
Senior Lecturer	1
Technical Director	2
Technical Manager	3
Technical & Product Manager	1
Technical specialist (production)	1
Tool Jig & Die Maker (uncertificated)	1

2. Findings

2.1 Plastics industry dynamics and issues

2.1.1 Respondent views on the status of industry strength and competitiveness

There was a strong contextual finding from the study that the plastics industry in South Africa, in general, is not globally competitive. Factors and circumstances perceived to contribute to this being the case are outlined below.

- ***Industry lacking a vibrant innovation culture***

A number of industry respondents cited a lack of an innovation culture in the South African plastics industry which corroborates findings by Garisch (2016). The industry is, by and large, a copier of global market trends, rather than a leader. This is particularly so in the packaging and colour matching industry where there is very little 'need' for home grown design and development.

> We wait for it to be developed somewhere and then we see it and say that's what we are after, that's what can work for us. R&D analyses what is in there and we just copy. So it's a very reactive sort of copycat type market. (Respondent 4, Manufacturing Manager, Company C)

South African companies, by and large, are feeders or copiers, rather than inventors and respondents felt that the industrialisation of new materials and products is only possible for large group companies. As a result, South Africa tends to "feed off a lot of international companies" (Respondent 13, Technical Specialist: Production (ex-GM), Company F).

This demise of an erstwhile world-leading innovation culture is decried by the industry who simultaneously recognise the existing capability and skills in South Africa, and the need to move to the forefront globally.

> I mean we do have the people here, we have the brains here. We need to get to the front of something again. It's time we do stuff that the rest of the world hasn't done yet. (Respondent 2, HR Manager, Company B)

One critical implication of this lack of innovation culture is that Polymer Scientists are correspondingly being limited in terms of opportunities, to come up with new products and processes.

> So your polymer scientists don't really have the opportunity to come up with an 'out of this world new packaging film', you know, that someone in Europe is going to say: "Ah look what they made in Cape Town, South Africa – we need to copy that". It's always the other way around… well, it's the case nine times out of ten. (Respondent 4, Manufacturing Manager, Company C)

- ***Prohibitive costs of imported materials and machinery a barrier to uptake by small companies***

Innovation and machinery development largely happens overseas because of higher levels of market demand for product. This results in South African companies becoming followers of technology and not actively innovating.

> We don’t have the machinery manufacturers here, it is all imported. Whether it is China or Germany or Italy it is there. That is where the stuff is made. So we are not part of that technical innovation … the companies overseas are creating that. (Respondent 19, Director: Sales, Company H)

And a similar picture emerges with materials where South Africa does not develop new materials. (Respondent 21, Project Manager, Company J)

The cost of internationally-developed materials and machinery is prohibitive for South African companies, in particular SMMEs. This results in limited new technology uptake, which negatively affects the country’s global competitiveness.

> That is the problem with the new technology in the plastics game, where you really have things like PVC-O that can be a game-changer. The prohibitive thing is the cost to get into it – and the royalties of course, because this is all European. (Respondent 20, Technical and Product Manager, Company I)

This reality holds special significance for the plastics industry in South Africa as it is dominated by smaller companies in general, whilst in the rotational moulding industry there are reportedly only 100 companies (with just one being a listed company), most of them family-owned businesses and each having a ‘niche market that is often geographically defined’ (Respondent 30, Industry Association A). Interestingly, in the rotational moulding sub-sector a company employing over 20 people is considered “large” (Respondent 30, Industry Association A) – which differs markedly from the standard Department of Labour definition.

It was furthermore noted that the smaller firms by and large operate more in ‘survival’ mode to keep overhead costs and input costs down as much as possible and, correspondingly, it is left to the large firms to drive process sophistication and innovation.

- ***Inefficiencies costing the industry***

The importance of optimisation and efficiencies are recognised in order to maintain global competitiveness. In general, it was felt that most companies do not run their machines efficiently, as per specifications, and in some cases, this could reportedly be as low as 50% efficiency. In this regard, cycle time, as an important component, was highlighted by one respondent.

> Our injection moulding department where we make the fittings is exactly the same as any other injection moulding plant all over the world. It’s all about efficiencies. You’ve got a cycle time, you’ve got to try and trim that cycle time down as much as you can. (Respondent 20, Technical and Product Manager, Company I)

The first reason cited for these low efficiencies, is a lack of technical and operational staff expertise to maintain the machines. The second reason cited was that staff did not have the ability to see the problem holistically in order to put optimisations in place, such as adjusting machine settings; or, in the words of one respondent: “…lack of understanding or seeing ‘what is happening’ – nobody sees the changes together in an interconnected way” [so as to optimize settings for process efficiency] (Respondent 12, General Manager: Production, Company F).

This was corroborated by another respondent who felt that low productivity levels and a lack of operational efficiencies were undermining industry strength and global competitiveness and if effectively addressed, this could potentially boost exports from South Africa.

> If you think about productivity in South Africa we are very far off. If you can get to the point where the operation is slick, cost effective, you can get going on exports where we know we are competing with China, India and Kenya. (13F Technical Specialist – Production (ex GM))

- ***Difficulty recruiting suitably qualified and experienced personnel***

<u>Engineers</u>

It is felt, at a professional level, that there is a critical shortfall in appropriately qualified and experienced people to recruit from – across all levels or job categories. In terms of engineering graduates specifically, it is felt that there has been a dramatic decline over the years in the pool of manufacturing "industry-ready" graduates in the electrical, mechanical and chemical fields. Those people with a formal higher education qualification who are good, are employed in the industry.

> When it comes to recruitment at that level where you require people with some formal type of qualification and more your professional people, I think companies struggle to find people because there's only a small pool of people who float around – the good people are always employed in our industry. (Respondent 5, HR Manager, Company C)

Another respondent (Respondent 16, Plant Manager, Company G) estimated that over twenty years the success in hiring a graduate engineer has dropped from 90% to 5%. A similar trend is found in the lack of availability of experienced technical managers, technicians and artisans.

<u>Technicians</u>

The lack of plastics sector focused training at a technical level in terms of both knowledge and skill was highlighted as a shortfall. This level of skill is 'imported' from Zimbabwe as a compensatory measure.

> I have not yet come across any South African recruits who studied polymer sciences on a more Technikon basis – technician-level polymers or plastics. All the people hired with the skilled [technical plastics] knowledge all come from Zimbabwe… they have a very strong polymer Technikon or institute, the likes of which we don't have in this country. (Respondent 12, General Manager: Production, Company F)

<u>Artisans</u>

Whilst this study's focus area is on engineers and technicians, industry respondents bemoaned the lack of a 'pool' of job-ready artisans available to companies and this is reportedly a particular scarcity in the *blow-moulding* industry. There was also a tendency to conflate skills profiles for technicians and artisans from a number of respondents.

> Our [blow-moulding] industry does not have a pool of capable artisans from which to draw … you will not find blow moulding-artisans ready-made for you. You don't find those people. (Respondent 12, General Manager: Production, Company F)

It is envisaged, that in the future, the critical scarcity of suitably qualified and experienced *red seal artisans* will be problematic for the plastics industry.

Industry also reported that what is stated on the CV or qualification of a prospective employee does not match the actual knowledge and skills when they are assessed 'on the floor'. A qualified artisan may have apprenticeship experience in another sector but finding *artisans with plastics industry experience* is difficult.

> So the big challenge here is that we need young, potential people who want to be millwrights and whereby they will understand the plastic kind of manufacturing. Some of them only have plain qualifications, they have never been … they have never worked in plastic companies. (Respondent 8, HR Administrator, Company D)

Another shortage decried by industry is *maintenance technicians* and *'all-rounder' artisans*, because new technology and machinery is compromised if you don't have all round maintenance skills. The current cohort of maintenance technicians in the industry are being phased out, but their all-round knowledge and skill is irreplaceable.

> Yes, you can put in new technology in, you can put all the machines can look uppity and fancy on the outside, but when it comes down to the grunt of it and the thing is broken, you need somebody who understands how to weld it, fix it, re-machine it and get it up and running…. You don't have to be experts at it, but they need a good working knowledge of it. (Respondent 2, HR Manager, Company B)

Experienced and qualified *tool makers* are another rarity ("unicorn") in the industry, especially in injection moulding.

Machine operators and setters and printers

At a machine operator and setter level in industry finding suitably-qualified technical personnel in extrusion presents a major challenge in the industry. In particular, finding people with a sufficient grounding in polymers to understand the product at each stage of production.

> You can teach people to run the machine – 'what will this button do, what that button will do'. But it is a problem to find a person who is qualified extrusion machine operator or setter who has a qualification in polymers – who understands what is happening to your product, who understands polymers … their properties and how they work. (Respondent 7, Production Manager, Company D)

Similarly, qualified printers who understand colours, solvents, inks and temperatures are a scarcity in the industry. Having suitably qualified and experienced printers is seen as critical.

[NOTE: Additional aspects concerning the Employment Status of Graduates in the plastics industry are considered in sub-section 2.1.2 below.]

Industry lags rest of world in terms of R&D investment and innovation-promoting outputs

South Africa lacks the laboratories that other countries have and this means the country lags behind the rest of the world in terms of research and development and testing. Part of the problem is a lack of funding (Respondent 30, Industry Association A), although there is recognition of the importance of having testing laboratories (Respondent 32, Industry Association C)

This results in little development and innovation particularly in pipe manufacturing where there is very slow adoption of new technologies in South Africa.

> But the uptake is slow because of the cost in South Africa. Overseas, there's – let me give you an example. P100 was developed in Europe in something like that and went into

> production in about 1992 – 1995. They only got adopted in South Africa in 2010. You see what I mean? (Respondent 32, Industry Association C)

Developments in new plastics materials take time to 'trickle down' into industry and there are challenges with getting civil engineering specifications aligned with new product developments in the pipe manufacturing industry.

With rotational moulding specifically, international research at the University of Belfast, Ireland is well funded by a large Petro Chemical company and is considered a world leader in rotational moulding research, including ground breaking research into biodegradable materials. In respect of the latter, an industry representative illustrated by way of the following example:

> So what I'm saying is that they have got the opportunity – it is a university, they have got a proper laboratory. When there's something that's happened – they even looked into the polymer lactic acid, this bio-degradable materials and they were doing things with banana leaves and this was six years ago already. So that's the kind of guys that you would be up against. (Respondent 30, Industry Association A)

- ***LEAN manufacturing ethos inhibiting job specialisation and, ultimately, development and innovation***

The increasing or pervasive impact of LEAN manufacturing ethos is bemoaned with respect to functionaries being required to perform more varied roles and functions and therefore becoming more multi-skilled. This has the knock-on effect of inhibiting job specialisation and the attendant adverse consequences for a company with respect to research and development or innovation.

A technical manager (Respondent 1, Company A), who is both a qualified analytical chemist and polymer technologist, provided a 'graphic' account of the adverse consequences of this approach to manufacturing with reference to a colleague, a rubber technologist at another of the company's plants, who had become increasingly drawn into production oversight and support for the company adopting LEAN manufacturing principles a few years ago (as has the respondent) at the expense of new formulations and optimisation:

> If he [rubber technologist] stands next to the line, it runs perfectly. If he keeps an eye on the drug room and how everything is mixed, it runs perfectly. But when he turns his back, then production does what they like to do and they make scrap.
>
> So he doesn't have time to sit in the lab and study rheology and new formulas and optimizing and develop and research. He had to be on the production floor. That's why you don't have rubber technologists that are specialists anymore, they are already depleted.
>
> I see it with myself. I would like to sit in a lab all day, but I can't.

- ***"Bad" structural dynamics and business approaches undermining company effectiveness and competitiveness***

An industry-wise plant manager drew attention to significant differences in operational approaches across companies, as influenced by an interplay of company structure, customer base and the business environment. In this regard, a warning was sounded about an undue focus on 'silo performance' to the detriment of the 'core processes' of the company.

> I worked in four of them [group of companies] and they have completely different approaches to their tasks and to – not so much tasks – but the structure and how much

> they are allowed to do. Massive differences, completely different outlooks from one company to another. (Respondent 16, Plant Manager, Company G)

Multiple silo structures in a single business were strongly criticised, as they fostered procedural compliance and an administrative burden that takes people away from production processes that are at the core of the business. This systemic flaw was exacerbated in the case of companies with overseas owners.

In contrast, it was felt that companies that are run autonomously with South African-based directors, have a closer link to customer demand and a single company philosophy. This meant they could run their own business and align their technologies with their business strategy.

> I can give you examples of such companies and you will see that although they have completely different customers, different products to each other, they all have one philosophy right and that is they make sure that they can run their own business by themselves. They don't need outside help. (*ibid.)*

- ***Ignorance about the (plastics) polymer industry***

Concern was expressed about evidential high levels of ignorance about the (plastics) polymer industry among both industry professionals and technical functionaries as well as young people-as-prospective students/ employees and the critical implications this holds for industry growth and strengthening. A higher education respondent drew attention to the following (Respondent 33, University A):

> Our experience has been that one of the biggest problems is a lack of knowledge amongst young adults about career opportunities in the polymer industry and therefore a lack of students coming into the study field.
>
> If you have a trained engineer/ technician approaching you with regards to polymer related queries, there is usually a lack of understanding of polymer properties and type, for example, simply stated; 'they would believe that all polypropylenes are the same'.

2.1.2 Engineers and technicians: current employment status and trends

The intention of this part of the study was to establish a baseline employment status and trend analysis of technicians and engineers in the plastics sector using ATR data from the merSETA over a five year period. It was hoped that the data would provide qualitative information to support the problem statement of a shortfall of technicians and engineers, in particular to provide evidence of numbers of people needing to be trained in future. However, the data proved to be of limited use in establishing baseline data.

One of the limitations of the ATR data used, was that only large firms input data for Mandatory Grant applications with the merSETA. In an industrial sector, such as plastics, which is dominated by small and medium enterprises, a large portion of the employment data is missing.

A second limitation is inferred from the industry views of the OFO codes (Section 2.1) that they are rigid and limiting, lack specificity and are difficult to interpret and apply. If this is the view of industry the potential for the incorrect allocation of codes and capturing inaccuracies would also affect the baseline data.

With a large five year data set, a third possible limitation is the inclusion of "non-plastic" firms in the data.

2.1.2.1 Baseline employment data analysis for engineers and technicians

Five years of data from the merSETA Annual Training Reports (ATRs) were analysed from 2013 – 2017, in order to reach a baseline understanding of the employment trends for engineers and technicians in the sector using the Organising Framework for Occupations (2017) codes. The ATR data, job titles and specialisations relevant to the plastics sector were extracted and collated for all plastics companies who submitted ATRs in the five years. It is important to note that in almost all instances, industry used the specialisations as opposed to the generic job titles when allocating the OFO codes while completing their ATR submissions.

Another important point to note, is that many small companies do not submit ATRs and as a result the analysis is dominated by larger companies where the skills sets are different to smaller companies.

- *Engineers*

Thirteen relevant job titles at an engineering level were identified and these came from the Major Groups: Managers, Technicians and Associated Professionals and Professionals. Industry relevant job titles taken from the "specialisations" were used to more accurately reflect the terminology used by the industry when working with the OFO codes.

Over the five years, the total number of engineering employees increased from 603 to 2027 in 2017, with a slight contraction in 2016. On average, 1377 people are employed as engineers in the sector over the five year period.

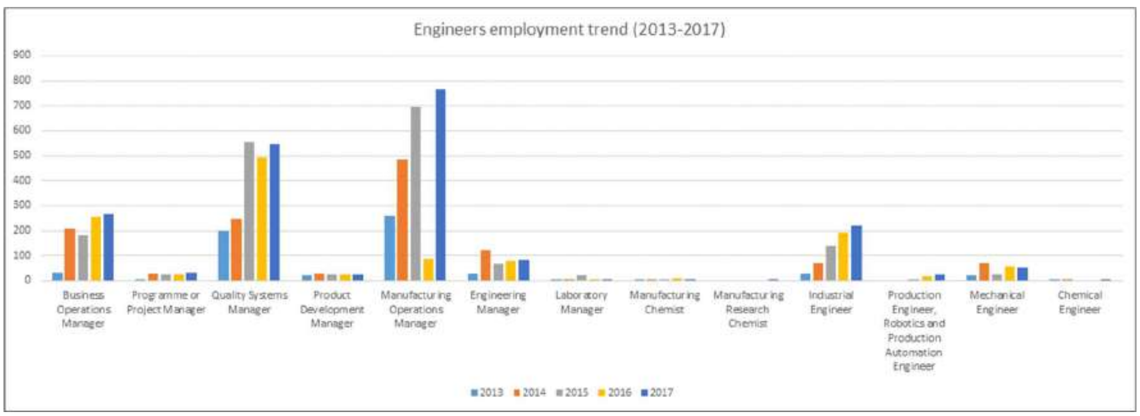

Figure 1: Engineers employment trend 2013–2017

Figure 1 above illustrates that Manufacturing Operations Managers (132102) are the largest engineer employment grouping, followed by Quality Systems Managers (121908) and Business Operations Managers (121901). All three show an employment contraction in 2016. Industrial Engineers (214101) are the one job title that shows consistent and steady growth over the five-year period.

Interestingly, Chemical Engineers (214501), Manufacturing Research Chemists (211302), Manufacturing Chemists (211301) and Laboratory Managers (134902) show very small employment numbers, which supports the view of limited research and development and limitations of technical laboratories cited earlier.

Whilst small, there is a steady increase in the employment of Production Engineer, Robotics and Production Automation Engineers (214103). This finding does support industry respondents' view of increased automation processes.

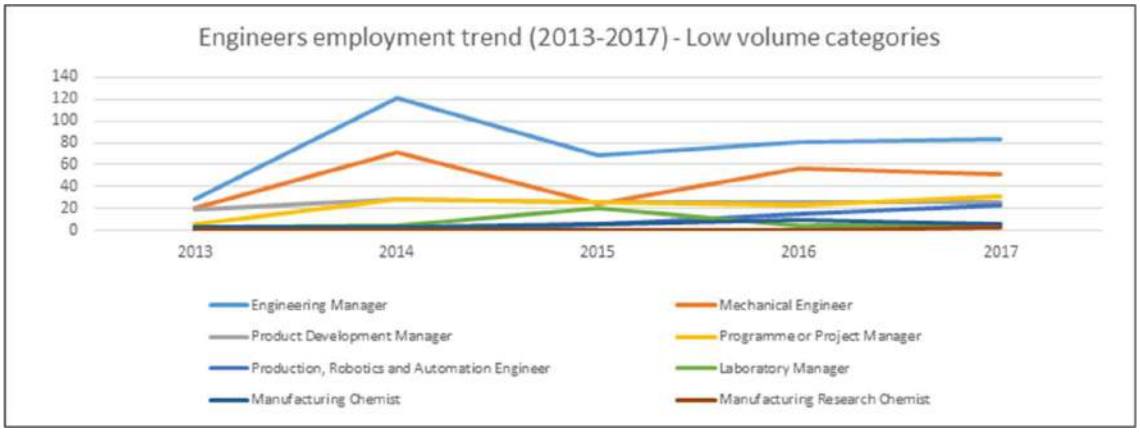

Figure 2: Engineers employment trend 2013–2017 – Low volume categories

The *low volume* job titles saw the largest growth with Engineering Managers (132104), followed by Mechanical Engineers (214401) and Programme or Project Managers 121905). Interestingly, Manufacturing Research Chemists (211302) are employed for the first time in 2017 and Production Engineer, Robotics and Production Automation Engineers (214103) are employed for the first time from 2015. This suggests a move towards greater automation in the workplace and a possible stronger focus on research within larger firms, who dominate the ATR data. Laboratory Managers (134902) reach a peak in 2015 with 20 people employed, but on average 4 Laboratory Managers (134902) are employed annually. Interestingly the employment of Mechanical Engineers (214401) fluctuates along with Engineering Managers (132104), with both exhibiting a dip in 2015.

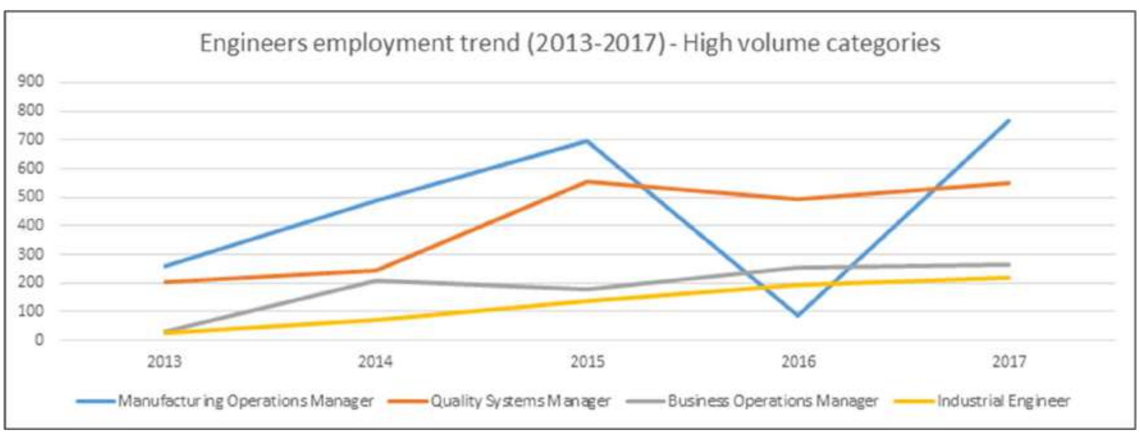

Figure 3: Engineers employment trend 2013–2017 – Large volume categories

The four *large volume* job titles were: Business Operations Manager (121901), Quality Systems Manager (121908), Manufacturing Operations Manager (132102) and Industrial Engineer (214101). The largest growth over the five years was with the Manufacturing

Operations Managers and the smallest growth was with Industrial Engineers. However, the Industrial Engineers have seen a steady growth rate whilst Manufacturing Operations Managers show a more volative employment trend with a significant drop in 2016 and 2017 barely returning to 2015 employment figures. Quality Systems Managers also experienced a small drop in 2016, but overall there has been a steady increase in their employment over the five years, suggesting an increased need for quality assurance oversight by industry.

➢ <u>*Technicians*</u>

Fifteen relevant job titles at a technician level were identified and these came from the Major Group; Technicians and Associated Professionals. Industry relevant job titles taken from the "specialisations" were used to more accurately reflect the terminology used by the industry when working with the OFO codes.

Over the five years, the total number of technician employees increased from 809 to 3499 in 2017, showing a greater growth rate amongst technicians when compared to engineers. On average, 2429 people are employed as technicians in the sector over the five year period. This is almost double the number of engineers employed.

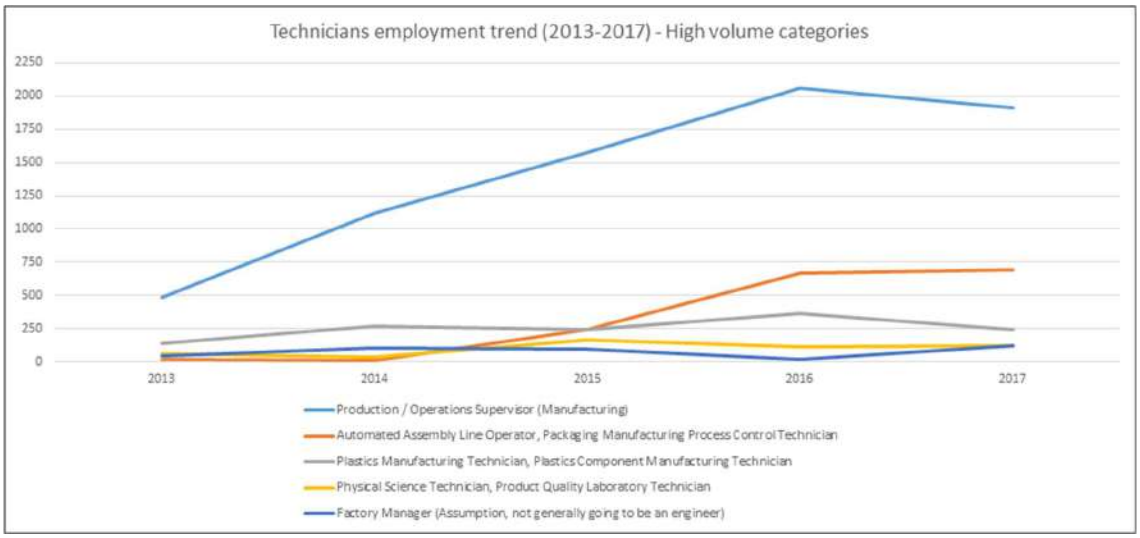

Figure 4: Technicians employment trend 2013–2017 – Large volume categories

In the *large volume* technician employment, Production/ Operations Supervisor (Manufacturing) (312201)) is the largest category with the number of employee's tripling over the three-year period and taking a slight dip in 2017. Automated Assembly Line Operator, Packaging Manufacturing Process Control Technicians (313901) show a marked increase from 13 employees in 2014 to 694 in 2017, indicative of an increase in automation, as was seen with the engineers. Over five years the number of Physical Science Technician, Product Quality, Laboratory Technicians (311102) doubles mirroring a similar increased focus on quality assurance as seen with the engineers. Factory Managers (132101) (assumed not to be an engineer), also more than double in numbers over the five years. The Plastics Manufacturing Technician, Plastics Component Manufacturing Technician (311904) category exhibited a steady employment trend over the five years.

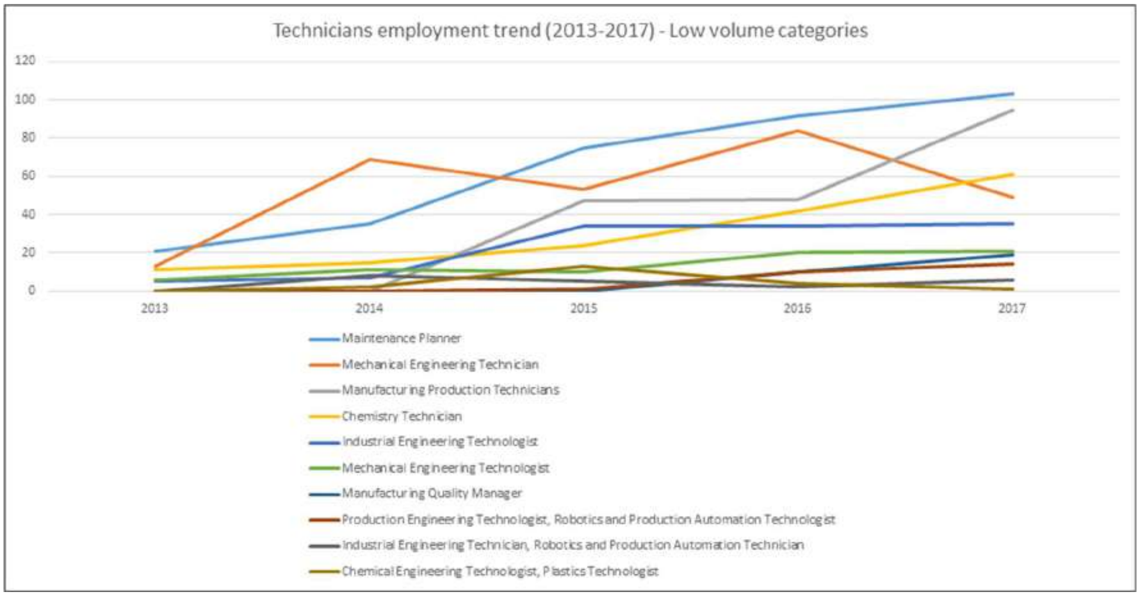

Figure 5: Technicians employment trend 2013–2017 – Low volume categories

The technician employment trends in the low volume categories become more complex. The four lowest employment categories with under 20 people employed per category as of 2017 were: Industrial Engineering Technician, Robotics and Production Automation Technician (311905), Chemical Engineering Technologist, Plastics Technologist (214502), Production Engineering Technologist, Robotics and Production Automation Technologist (214104) and Manufacturing Quality Manager (132106). The complexity of job titles suggests that perhaps identifying the correct OFO code to use for these positions is challenging for industry.

For the remaining six employment categories, the largest steady employment growth area is seen in Maintenance Planners (312202) with numbers growing from 21 to 103 over five years. Mechanical Engineering Technicians (311501) also demonstrate growth, but there are significant fluctuations that do not mirror the overall trend of the other employment categories. Manufacturing Production Technicians (313916) also show steady employment growth with technicians only starting to be employed in 2015 and almost doubling by 2017. Chemistry technicians (311101) grew from 11 in 2013 to 61 in 2017 and Industrial Engineering technologists (214102) grew from 5 in 213 to 35 in 2017.

What is interesting to note in Figure 4 of the low volume technician employment trends is the move to differentiation of the different occupations over the five years, suggestive of a better understanding and utilisation of the OFO codes over time.

➢ *<u>Job titles not in the Annual Training Report</u>*

There were four relevant job titles and specialisations, one would have anticipated finding in the data analysis, but which did not appear.

A Commercial Digital Printer (662216) is defined as someone who “Sets up, operates and maintains a variety of commercial digital printing equipment to print specified printing jobs on a variety of substrates such as paper, vinyl and plastic”. In the flexibles and packaging industry one would have anticipated possibly finding the allocation of this code, but in the five years of data, this job title did not appear.

Similarly, a Materials Engineer (214907) with Specialisations of “Materials and Non-Destructive Testing Engineer” and “Materials Science Engineer” does not show up in the data. At a technologist level, a Materials Engineering Technologist (214908) also does not appear in the data analysis.

A Materials Scientist (211403) who “Studies the properties and uses of non-metallic materials and advises on the technical aspects of their manufacture and processing”, with a specialisation of a “Polymer Scientist” also is not captured in the data.

It is possible that these jobs are handled by testing facilities, or alternately, roles are combined with other management roles or job titles and therefore they do not get allocated by industry when submitting their ATRs. This does illustrate a weakness of the OFO code allocations that may not take into account the conflation of roles and responsibilities.

- *Skills: Agricultural, Forestry, Fishery, Craft and Related Trades Workers*

Data was captured under this artisanal category, from the ATRs, as industry can from time to time conflate technical work and artisanal work. This data is not analysed in detail, but it should be noted that the shortage of qualified artisanal workers reported in the study is corroborated by low employment figures for qualified artisans in the plastics sector in the ATR data.

- ***Conclusion***

The data shows an increased employment trend for engineers and technicians in the plastics sector suggesting that there continues to be a demand for suitably qualified personnel in these categories. The drivers for quality production and well managed production processes are seen in the growth of numbers employed in related roles.

However, as a baseline picture of the employment of engineers and technicians the data *directly contradicts* the opinion of the majority of respondents who cite difficulty in recruiting suitably qualified and experienced personnel, a limited need for engineers and declining employment prospects for polymer scientists. These opinions are outlined in the respondent views below. This dichotomous finding of the study, suggests that ATR data should be used with significant caution and is a possible area of future study, to examine why the employment data is anomalous to industry opinion.

2.1.2.2 Respondent views on employment status

Engineers

The current employment status of engineers in the plastics industry is limited in terms of formally qualified personnel and it was felt that, in general, only larger companies employed engineers. For the most part, companies feel that formal engineers are not needed in the industry, especially those with low levels of specialisation. However, there is an awareness that there may be a future need.

> We don’t have engineers and technicians and that. I’m not saying it’s not needed, maybe there is a need for it. But we seem to get on without them. (Respondent 4, Manufacturing Manager, Company C)

The current engineering requirements seem to be addressed in ‘non formal’ ways. For example, engineers may not be required for the day-to-day running of the business, but they may be needed for *special projects*.

> “We don’t have engineers here to talk of… not full-time. I don’t see that there’s a fulltime position. But even though, I mean some of the stuff that the people do here is that but it’s just not formalized.” (Respondent 2, HR Manager, Company B)

In those companies that do employ engineers, there is a *gap between the engineers* who come up with formulations and have a strong principled knowledge base and the *technical managers* who implement the manufacturing processes, setting up and running machines.

As is highlighted in other sections of the report, there is a need for hands-on practical experience, as well as the theoretical knowledge gained through a formal engineering degree.

> “So he’s got this incredible knowledge base, but he hasn’t got the hands-on experience. The rest of the managers are more sort of manufacturing, hands-on sort of management level.” (Respondent 4, Manufacturing Manager, Company C)

Whilst there are *very few qualified engineers employed at present in the industry*, the engineering function and responsibility is often ‘seamlessly’ handled by a highly capable technical team who have varied skills sets and experience, as an HR Manager explained (Respondent 10, Company E): “We don’t have an engineer per se in the academic sense but we have people like our technical director who are performing engineering type work”. This effectively results in a *‘blurring’ of engineering and technician competences* in the workplace.

> “We are using engineering and technical interchangeably in our case…but it’s serious engineering work. We haven’t discussed to say we need an engineer in our plant because our technicians fulfil engineering requirements and responsibilities.” (ibid.)

However, it is emphasised that this technical ‘clustering’, which merges the engineering, technician and artisan competences, is *only successful in relatively small companies* where this teamwork is more easily facilitated.

Looking to the *future* the picture looks different and companies *start to make the case for employing qualified engineers and technicians*. Importantly they identify a *separation of function* which is currently not the case, as illustrated above. Industry feels that engineering graduates will develop engineering systems because they are trained to look at *systems* and suggest areas for improvement. The *holistic thinking* of an engineer is seen as advantageous when system dynamics must be unpacked and re-built. Technicians, on the other hand are viewed as the systems implementers. So, a distinct difference is seen as advantageous in future, with *engineers developing systems and technicians implementing systems*.

> “…in the long term to get an engineer will benefit the business because they are always looking at how to do things better, putting systems around things. We need systems. That’s why an engineer would be more useful. “Technicians will then roll out a system.” (Respondent 10, HR Manager, Company E)

<u>*Polymer Scientists*</u>

Limited / decline in employment opportunities

Polymer Scientists currently are *only employed in product development where there is a research and development focus.* This means that companies without R&D capabilities will not employ Polymer Scientists. This results in limited, if not a decline in, employment opportunities and scope for Polymer Scientists focused on materials science as well as Chemical Engineers.

Industry reported that Polymer Scientists are *mainly employed by raw material suppliers and large master batch producers*, as well as *large convertors*. However, the technical and laboratory services at raw material suppliers and large master batch producers have declined, possibly due to cost implications, and this has resulted in an attendant decline in employment opportunities. This has resulted in a decline in technical service laboratory expertise and degreed scientists have been lost to the industry.

> "We were forever talking to highly trained people – there you got a place for a degreed person because you are talking different materials, different processes. But they don't exist anymore. So that is a gap that has opened up." (Respondent 13, Technical Specialist: Production (ex GM), Company F)

Process Technicians

As discussed above, technicians are seen as the 'implementers', responsible for the machine settings and production runs, in line with the company quality management system. In many instances, this is aligned to the ISO 9001/2015 accreditation held by a company. The maintenance of machinery and the correct operation of software is strongly procedural and must be documented to ensure compliance with ISO. These process technicians work on the shop floor ensuring the running of the machines and that the resultant product quality meets standards.

Quality Control Technicians and Laboratory Assistants

This group of technicians are not working with machinery as do process technicians. They require training in *good manufacturing practices, good laboratory practices and they must have good work organising skills*. On top of this they require a *specific technical skill* relevant to the sub sector they work in, for example, in colour matching …"it is a very niche skill, for example, how the different pigments would react with the different polymers and temperatures" (Respondent 14, Quality Control Manager, Company F).

It is in these specific technical skills, that industry identifies a training shortage. Whilst there is basic polymer training available, appropriate *colour-matching* training cannot be readily sourced. The same respondent puts it as follows: "We haven't been able to find anything. I think there was in the past a few years back, but apparently that course is no longer available". (ibid.)

Artisans

Whilst the core focus of this study was on Engineers and Technician training and education, it emerged very strongly that artisans are a critical skill requirement in the plastics industry. Millwrights in particular are the core of technically-skilled maintenance employees. With different machines used in different departments (e.g, extrusion, printing, conversion, logistics), there is a strong need for maintenance which is done by millwrights.

"We have different machines in the departments. We have the extruder machines, we have printing machines, we have the slitting machines, we have the bag making machines – so all those they have to be maintained by qualified artisans." (Respondent 8, HR Administrator, Company D)

2.1.2.3 Job title and function differentiation in relation to company size

Job titles and job functions are differentiated by company size. In the past job titles had greater differentiation in larger companies than in smaller companies. As discussed under the employment status of engineers and technicians above, there is now an increasing ‘blurring’ of titles with engineers working on machinery and equipment and diploma engineers being given a similar status as university engineers.

This carries through at a company level where the title of engineer is given to lower level qualifications, especially in smaller companies, as explained by a General Manager (Production): “I think that happens lots more in smaller companies where they give the terminology a bit of a more senior position essentially to a lower spec’d position” (Respondent 12, Company F).

Importantly, whilst job titles may be the same across large and small companies, generally the *scope of work is much broader as company size decreases*. This means that employees must have a broader knowledge base than their job title implies.

> In our case, if you are a setter that means you can set the machine. You have got knowledge of electrical, you have got knowledge of the watering cooling channels, and you have got knowledge of all of those processes. Everything to do with manufacturing on a factory level, you have to have knowledge of.” (Respondent 2, HR Manager, Company B)

This means that in *small companies* there is multi-job performance preferred over job specialisation and *specialised expertise is contracted in when required* if the company owner cannot solve the problem, e.g. electricians or electronic technicians. Conversely, in large companies, there is *more scope and resources for employing specialist high level functionaries*.

However, this is not hard and fast, and one industry respondent felt that there was a need for multi-tasking and ‘crossing boundaries’ regardless of company size. It was felt that regardless of company size and structure there was a *move to multi-taking and joining tasks in both small and large companies* and LEAN manufacturing as a trend could also be contributing to this shift. Although, as discussed earlier, this is also seen as a negative trend that contributes to theincreasing proceduralisation of work.

In terms of management functions, respondents identified three different management roles:

i) General Manager and Production Manager with differentiated and designated roles in larger firms
ii) Production Managers who understand the business side and drive costings and wastage
iii) An ‘all-in-one’ Manager with technical expertise, for example, a composite role often taken on by small company owners (founders)

2.1.2.4 Appointment and Promotion Criteria

In this part of the study, we sought to understand on what basis appointment and promotion in companies takes place. For example, is it strictly qualification driven, or skills-set driven, or a combination of both, or are other factors taken into account?

Appointment

In terms of higher level technical and management positions, in the past smaller companies appointed and promoted based on ability, whereas larger companies generally required qualifications. An engineering qualification was needed if one intended to reach management levels. Today, it is felt that the technician/engineering distinction is falling away and a technician is not considered any less competent than an engineer in some instances.

> "We haven't discussed to say we need an engineer in our plant because our technicians fulfil engineering requirements and responsibilities." (Respondent 10, HR Manager, Company E)

> "Just because you are a technician doesn't mean you are any less competent than an engineer." (Respondent 12, General Manager: Production, Company F)

Industry experience is considered more important than qualifications for production staff, due to qualifications not covering everything that is needed and due to the differences in how individual plants and factories are run; as a HR manager (Respondent 2, Company B) explained: "In that case, we are hiring experience, we are not hiring qualification – there is no real qualification that gives you the whole A – Z on a production plant. And I also think that there's a huge variation in how different people run plants".

Management and supervisory level

At a management and supervisory level, *in-house development* is strongly favoured compared to externally-recruited candidates due to the process and machinery specific knowledge and experience acquired on the job. When people are recruited externally at a management and supervisory level it is felt that they do not last because they cannot cope with the pressure of the company work environment and they don't understand the processes and machinery settings.

> "If one of our production managers has to leave now, like the current guys that's in place, it is very difficult for us to find a replacement for those people. Like the person that's in charge of our bag making and our co-extrusion of five-layers – there isn't a lot of people out there [that can replace them]." (Respondent 5, HR Manager, Company C)

Post-Graduates (Polymer Scientist)

At a post-graduate Polymer Scientist level, the main criteria used for appointment are evidential interest in production processes and an understanding of the company, based on a day's visit to the factory. This is closely related to appointment criteria that consider a candidate's compatibility with company culture, in smaller enterprises in particular.

> "So while the obvious starting point is qualifications and experience, a further critical factor is whether a person is going to fit into the company culture – when they don't fit into the company culture they just really battle." (Respondent 4, Manufacturing Manager, Company C)

Aptitude and attitude

In addition to the points above, industry felt that the *'right' character and attitude* as well as the *'right' knowledge* base was crucial. A *willingness to learn* and better oneself is considered important as well as a technically oriented *aptitude* at both a management and an operator level. Generally, the *mind-set of employees and how they apply themselves* in the workplace trumps a long list of qualifications when it comes to the appointment of personnel.

Interestingly, one company expressed a preference for employing an ‘average engineering graduate’ who has ‘struggled’ and will see the job as a ‘career’. On the other hand, a graduate who obtained high marks all along is considered a potential liability, as they are reportedly inclined to only use the employment opportunity to gain industry experience and then return to University to pursue a Masters or Doctoral degree. A Production Manager commended the former graduate type and the value they add as follows:

> “… the average person who did engineering degree in four years after so much struggling, he will never think of doing a Master’s degree or PhD degree. He will stick to the job and he will put effort into it and he will think, he will think left and right. A street smart person is important.” (Respondent 7, Company D)

The appointment and training of *apprentices* for tool room and engineering shops highlight a need for higher level entry qualifications in Maths and Science than the mandated N2 qualification: “We try and push our people to go do an N4 level of Maths and Sciences. We also offer them the opportunity to do that after they have started here.” (Respondent 2, HR Manager, Company B)

Promotion

Internal promotion is preferred to external appointments and for senior and technical positions, an employment agency is used. Internal promotion is linked to in-house training based on performance monitoring and aptitude.

Other criteria noted by respondents regarding promotion relate to personal attributes, for example, ‘mind-set’ of employees and how they apply themselves in the workplace, reliability, accepting of responsibility, time-keeping, and communication and interpersonal people skills – with particular reference to technically skilled staff being considered for promotion to supervisory or managerial positions.

A company culture of working your way up from the bottom is dominant, with one company citing the promotion of someone from operator to production manager over a 21 year period (Respondent 2, HR Manager, Company B).

2.1.3 OFO Codes

HR managers were requested to share their views on the alignment of current OFO Codes to company job designations and descriptions as well as their ease of use, or not. Their responses are captured below.

Rigid and limiting

Industry felt that the OFO codes are too limiting in descriptors to adequately fit industry job titles. They also felt that the codes did not adequately address differences in performance and wage differentials, as explained by one HR Manager:

> "So there comes a discrepancy in rates of pay… an operator isn't an operator, isn't an operator. There's some guys here that are earning supervisor wages, but they are performing a machine operator's job. But they do it so well I never want to lose them." (Respondent 2, Company B)

Burdensome and meaningless (lack of specificity)

Aligning job titles with OFO codes is seen as a burdensome exercise for the sake of compliance because the codes are so generic that in many cases it becomes meaningless because the codes lack industry sub-sector specificity. Aligning the workforce profiles with the OFO codes for ATR and WSP submission is seen as very time consuming; as articulated by another HR Manager: "It is not sufficient for what we do… a lot of the stuff is not even applicable to our company (Respondent 5, Company C)."

The OFO codes are difficult to interpret and apply because the descriptors do not reflect the workplace reality of job occupations and designations. This often results in a 'best fit' choice being taken when completing Mandatory Grant returns.

> "I didn't like them. I don't know where they are coming from, because some of them are not specific to our situation like I thought they would be. So you end up taking the nearest one." (Respondent 10, HR Manager, Company E)

Some respondents, production-based personnel, had no idea what OFO codes were and had "never heard of them before".

"No problems…just fine"

Respondents who hire Skills Development Facilitators (SDFs) to complete Grant applications to merSETA, reported no problems with alignment of the OFO codes and the job titles and descriptors, suggesting that the 'interpretive understanding' of SDFs removed any burden on industry to select appropriately aligned codes.

2.1.4 Knowledge and skills shortfall

2.1.4.1 Professional/ technical knowledge and skills

Engineers

Problem-solving (abstract) skills significantly lacking among engineering graduates

Reflecting on his own initial training as an engineer many decades ago, a Plant Manager bemoans a 'distinct' shortfall in problem-solving capacity among the 'new generation' of engineers (emphasis by researchers):

> "I could use [when entering first job] roughly one or two percent of what we were taught at Technikon [with reference to content]. However, the one thing that they did teach me – and with a lot of the modern engineers I don't see them having this same skill set – *we were taught to solve problems, from a very abstract perspective*."
>
> "The problem [now] with South African *engineers is that they are not taught to find the problem*. In the engineering disciplines, 90% of the focus should be on identifying the problem and getting that correct – only 10% of your time [in a work environment] is required to work on the solution." (Respondent 16, Company G)

[NOTE: Knowledge and skill shortcomings in regard to newly-qualified engineers and scientists is further considered in the next section (2.2) on "Education and Training of Engineers and Technicians']

Process Engineer

A process engineer is becoming a scarcity due to developments with machinery and robotics. Previously this role would have been filled by a Mechanical Engineer with on the job learning. Now what industry needs is a true all-rounder with regards to inter-disciplinary engineering knowledge and skill (mechanical, chemical, electrical, robotics/mechatronics and soft skills.

> "So he's now a generalist. He needs a lot of different stuff, he needs to know about the "flow of plastic through the hole" [all that it encompasses re optimal process]. Okay and on top of that, he has got to be able to train all the people who run the machines. So he's got to have people skills. So I think that it's a completely different animal you are looking for." (Respondent 16, Plant Manager, Company G)

Production and Technical Managers

At a production and technical manager level there is a need for a higher level of training focused on conceptual / analytical and process thinking, rather than specific knowledge acquisition. This 'way of thinking' is more holistic than 'knowing a recipe' for a product.

Machine Setters & Operators

In light of respondents' earlier-noted opinions on efficiency optimisation as regard 'running of machines', it was felt that understanding *how to make machinery run properly was a baseline skills requirement*.

The bulk of the need for these skills is at a machine setter and operator level. First and foremost, the requirement is for the *'right mind set' where analytical and integrative skills are needed* by setters and operators. Learning to *make adjustments to machinery in an integrated and nuanced manner* is only considered possible with experience and training. Industry felt that machine setters and operators need to have a technical aptitude in addition to a good baseline knowledge of maths and polymer science knowledge.

> "I would think the bulk of the need at the moment, is skilled machine operators. You want your operator to firstly to understand what it is that you are setting out to achieve and know what to do in the course of adjusting a machine. And we are not talking huge adjustment, just a little bit here, a little bit there." (Respondent 13, Technical Specialist: Production (ex GM), Company F)

Ideally the industry would like to see machine operators and setters who take care and pride in what they are doing and practice *'good housekeeping'*, keeping the work area and the machinery clean.

2.1.4.2 Professional (non-technical) knowledge & skill and personal attributes shortfall

- *Management skills*

It is felt that there is a deficit in management and supervisory skills particularly with respect to production management and warehousing management.

- *Interpersonal / communication skills and, by extension, collaboration and team work capability*

Engineers / Scientists

One respondent bemoaned a lack of interpersonal or people skills among newly-graduated engineers who lack people skills, with critical consequences for collaboration with team members.

> "The engineer or the scientist doesn't understand that there's people that act and think differently to them. They don't get it. For example, there at [Company] you have skills sets that will blow your mind… I mean there are guys who are absolute stars, they are rocket scientists. But as you know with very clever engineers, come lots of people problems...lacking interpersonal and communication skills or a sense of 'realism', for example." (Respondent 16, Plant Manager, Company G)

(Polymer) scientists and technical personnel are critiqued for a lack of *interpersonal or people skills*, as well as an ability to *communicate* in a non-technicist way with production staff, as articulated by a Manufacturing Manager (Respondent 4, Company C):

> "These polymer scientists and technicians, they are not wired for people skills. For example, when P [a polymer scientist] talks to me sometimes, then I say: Listen P, don't ask me to be a polymer scientist – draw me roadmaps, talk in my terms what you are trying to say."

Reflecting on his experience of having to navigate the social environment at the workplace straight after graduating, the particular polymer scientist referenced above lamented his under-preparedness in these regards as follows:

> "I think *generally* there in the academia – not specifically now focusing on polymer science – you get to an Honours or a MSc level, you are kind of pushed into PhD and then you are pushed into R&D and you are sitting in a lab and doing research and development. You are *never really exposed to inter-personal interaction* in a sense or *managerial skills*. So I think in any academic institute, they need to bring interpersonal skills and managerial skills into it." (Respondent 6, Technical Manager, Company 4)

Middle management

The packaging industry representatives, in particular, bemoan a lack of people management skills at the level of middle management in cases where personnel have been promoted from the shop floor – that is, they are ill-equipped to manage a large cohort of staff, with critical consequences given the labour intensive work environments in which they function.

> "No disrespect to the individuals, but a lot of it is people that are sort of just come from being promoted from their experience and age and at that [middle management] level … he just sort of sits there without the people skills, the management skills and those sort of things." (Respondent 4, Manufacturing Manager, Company C)

Technical personnel

A similar pattern is also identified with lower level workers, who become experts in their field, or trade, and then get promoted to supervisory positions. But in many instances, they don't make good leaders as they are not equipped with the right people and management skills and this can have critical implications for production and set the individual up for failure.

This lack of *interpersonal people skills* can also preclude the technically skilled staff from even being considered for promotion to supervisory or managerial positions.

> "He might become the senior colour matcher but he's never – I will not say never, but it's unlikely that he will become a laboratory manager because he doesn't have the greatest people skills… and its not going to happen." (Respondent 13, Technical Specialist: Production (ex-GM), Company F)

In order to *address this dichotomous problem of supervisory promotion and technical expertise*, one company uses a *dual system of advertising* a position internally and simultaneously identifying individuals they believe are suited to the position.

> "And then the person doesn't have the guts to tell 'Sorry, I'm not interested' because they don't want to offend you. But we do it in a dual way, where we know we can see because what is important in terms of the next level, is the leadership ability of the person." (Respondent 5, HR Manager, Company C)

A shortage is identified at a technician level and artisan level and not at an engineering level. In this instance the need is for *"fully-fledged and properly-trained" plastics technician or artisan* (Respondent 12, General Manager: Production, Company F) where a strong foundational basis in plastics technology is needed.

The other shortage identified by industry is *automation specialists or electronics technicians* due to most equipment have PLCs installed. Currently this skill is largely outsourced to contractors who are busy and difficult to call in for small jobs.

> "Even the electricians of today should know basic PLCs and basic fault finding of PLCs and the electronics systems. They really do need to know it but they do not – they come out and it's like they get into a tizz because they have no idea what is going on." (Respondent 12, General Manager – Production, Company F)

- *Administrative skills*

In terms of production staff on the shop floor, industry feel that there is a need for *administrative skills* that will allow staff to read job cards, work out materials and understand product and volumes.

- *'Right' attitudes*

When first employed, *post-graduates* are reportedly often inclined to adopting an attitude of seeing themselves as *"too good [highly qualified] to work/ learn on the floor"* and as a result they foreclose on opportunities to obtain vital practical and process knowledge. One reason offered is that entering industry (maybe not by choice) is perceived to be a 'step down' or self-limiting – that is, compared to being employed at a research laboratory.

Technical personnel are critiqued for a lack of responsibility and a sense of urgency. This is seen in 'clock watching' and a lack of investment in the job.

- *New / different knowledge and skills required for future*

In general, industry felt that core processes in plastics manufacturing will remain largely unchanged in future. Technology and materials may change but cost will always be an important consideration.

> "Of course there will be additional skills required. We will have to have people that are more computer literate, we will have more integrated systems, we will have better monitoring systems and so on. But I don't foresee the concept of injection moulding really changing or becoming obsolete." (Respondent 2, HR Manager, Company B)

Beyond technical skills

In a related point, industry highlight the need to look beyond technical skills to process management, managing people, organisational skills and computer skills in order to meet production deadlines as promised to customers.

Focus on people / interpersonal skills

> "At university we need the university to work on the people skills, especially of engineers. The engineer or the scientist doesn't understand that there's people that act and think differently to them. They don't get it." (Respondent 16, Plant Manager, Company G)

Managers require more all-round business knowledge and skills

This need starts with data gathering and monitoring of the production process and then applying business principles to the system to better understand manufacturing optimisation and machine replacement costs.

2.1.5 Training opportunities in industry

2.1.5.1 Internal / in-house

Internal in-house training is a major component of up-skilling staff in the Plastics sector. For companies with international linkages this results in international level skills transfer with international experts conducting the training, which is closely aligned to the production processes and machinery used in the company. One respondent in particular highlighted the link between internal training and maintaining records and the need for staff to understand processes and to problem-solve: "He had that department for three years and the skills that he shared, it is so, so good. You can see the transformation in the guys" (Respondent 8, HR Administrator, Company D)

For effective in-house training, one company believes there needs to be a department specific annual training plan with monthly refresher courses, for each of the different departments in a company. Should there be a customer complaint, the company will implement an ad hoc training session to ensure staff understand and the problem is not repeated.

> "Every department does its own training. So there's a set training schedule for the year where extrusion guys will get training of one thing, printing will get this skill, conversion will get this." (7D Production Manager)

For companies that are ISO compliant, there is a strong driver to ensure all staff go through training to maintain the necessary standards, as directed by the ISO documented framework. In addition to this, one respondent highlighted the need for apprentices and artisans to shadow technicians and technical directors prior to taking a trade test.

2.1.5.2 External (industry-based)

Plastics SA

External training opportunities are primarily offered by Plastics SA and taken up by industry. Respondents are positive about the training courses, but they do emphasise that the focus is on general polymer knowledge that prepares people to become "technically certificated without any specialisation". The blow moulding industry in particular reported the shortage of specialist knowledge. The personal development and mind mapping skills taught by Plastics SA are seen as very beneficial by industry in addressing some of the soft skills deficit.

> "When you send people there, we don't send them so that they can become better process technicians or better in what they do. We send them more for their own growth so that they just grow as individuals, then they grow and then they can start adding more value – not just in front of the machines, but as individuals." (Respondent 10, HR Manager, Company E)

Industry feels that the next step from the technical skills offered by Plastics SA is to develop fully fledged artisans who industry feel are one level below a formal engineering qualification. Again, this illustrates the conflation of degrees, diplomas and artisanal training.

Institute of Packaging of South Africa

The Packaging Technologies short course offered by the Institute of Packaging of South Africa, is viewed as beneficial by those working in the plastic packaging sector and it is felt that staff who attend the course share their learnings with others on the shop floor afterwards.

2.1.5.3 Training provision (system) shortcomings

- <u>*Generally*</u>

In general, it was felt that industry-wide and specific training is desperately needed in the plastics sector. However, it was expressed that a pervasive and entrenched reactive culture of 'we'll make a plan' effectively undermines the establishment of a systematic and industry needs-driven knowledge and skills development intervention. This corroborates and supports a similar view raised in the Plastics Chamber research of 2016 (Garisch).

> "I don't think the plastics industry will ever die, but it will always be the same old story of 'we will make a plan'. Well making a plan is not good enough. You have got to make a plan based on trained knowledge." (Respondent 13, Technical Specialist: Production (ex-GM), Company F)

- <u>*Higher Education level*</u>

At a Higher Education degree and diploma level, industry feel there is a need for training especially with technological developments, but they also say that there are *too few plastics industry-focused courses* on offer at this level.

> "But if you look at how many degrees you can do on plastics, it's tiny … only a handful of people go through doing a degree and we don't have enough technology coming into the market." (Respondent 15, Technical Manager: Production, Company F)

- *Intermediate level*

At an intermediate level, the *demise of the apprenticeship system* is bemoaned as, from an industry perspective, it is viewed as the best mode for knowledge transfer. There is recognition of systemic short-comings in artisan training and development in the plastics industry. For example, there is no formal training provision for blow moulding artisans. This means there is no pool of blow moulding expertise to draw on, and as a result it leads to head hunting/poaching staff from the opposition or training staff in-house.

Another shortcoming is the lack of formal specialist training for colour matching (not polymer training), whilst acknowledging the limited opportunities for employment in this field.

> "We are a processing company – we do colour matching but we don't need polymer training for that. There's no training for colour matching. If there was a facility for training and colour matching that would be good, but limited scope for employment but it's good." (Respondent 13, Technical Specialist: Production (ex-GM), Company F)

- *Technical and Vocational Education and Training (TVET) Colleges*

The TVET college apprenticeship theoretical training component was strongly criticised and companies now use private colleges even though it costs significantly more.

- *Supplier training*

Industry perspectives on supplier training are mixed. On the one hand the supplier training offered by Sasol (the largest manufacturer of polymers in South Africa) is seen as very beneficial to the company because it is directly related to the raw materials and processes, and certificates are issued.

> "We started sending our supervisors to them for training courses. They teach them about polymers, the properties of polymers, how it performs on your machines, what important things you need to check." (Respondent 7, Production Manager (GM Ops), Company D)

On the other hand, some suppliers have shut down their technical centres and there is uncertainty as to whether Sasol is being fully utilised.

Other suppliers are critiqued for not having sufficient technical polymer knowledge. It is felt that raw materials suppliers are focused on sales orders and may not have the technical knowledge, or sharing technical information becomes secondary to the imperative to secure more sales orders.

> "But other suppliers, we don't come across that many who are able to provide input into what we are doing. And I think it is a gap really, probably reflecting on the limited technical knowledge of the people selling polymers." (Respondent 13, Technical Specialist: Production (ex-GM), Company F)

2.2 Current Higher Education (HE) provision in regard to polymer (plastics) industry

Introduction

Against the backdrop of the foregoing 'industry' overview which considered aspects concerning employment patterns and related aspects, as well as demand-side skills shortfall with respect to engineers/ polymer scientists, technologists and technicians, the focus now shifts to plastics industry-aligned provision for these functionaries, that is, at HE level (NQF Levels 6–10). The current status of qualifications and programmes (including short courses) will be presented as well as research focus areas of the departments under whose auspices programmes are offered (Masters and Doctoral level studies) – followed by supplementary or clarificatory comments by HE respondents concerning key issues of relevance.

Finally, industry respondent views on current HE provision will be presented which, apart from being 'evaluative' in focus with regard to both the quality and relevance of the qualifications/ programmes and the nature of graduates produced, will also be illuminative of industry awareness or understanding of the 'dynamics' that govern HE provision and the implications thereof for enhanced collaborative engagement and mutual support in view of plastics industry strengthening (which indeed comprises the final part of findings presentation).

NOTES:

i) The listing of qualifications and programmes of relevance is done by way of 'at a glance' (summary) tables, the scope of which spans HE institution, Department/School of relevance, and the Qualifications/ Programmes with respect to Titles, NQF Level and Duration (costs-related aspects will be considered in the follow-on commentary section).

ii) In-depth information on the respective qualifications/programmes is presented in Annexure 3, with particular regard to Admission Requirements and (individual) Course Outlines. Salient aspects concerning the latter will be referred to in the Comment section below.)

2.2.1 Qualifications and Programmes

2.2.1.1 Undergraduate level

Table 3: Plastics industry-aligned qualification and programme offerings: undergraduate level

HE Institution	Department / School	Qualification	NQF level	Years
NELSON MANDELA University	CHEMISTRY	National Diploma in Polymer Technology	6	3
		Diploma in Analytical Chemistry	6	3
		Diploma in Chemical Process Technology	6	3
		Advanced Diploma in Analytical Chemistry	7	1
STELLENBOSCH University	CHEMISTRY and POLYMER SCIENCE [15]	BSc in Chemistry and Polymer Science	7	3
		BSc in Textile and Polymer Science [16]	7	3
		BTech in Polymer Technology → *To be phased out at end of 2019*	7	1

[15] The only Chemistry Department in the country that is officially designated as a Department of Chemistry AND Polymer Science

[16] In 2019/ 2020 to change to 'Materials Technology and Polymer Science'.

HE Institution	Department / School	Qualification	NQF level	Years
TSHWANE University of Technology	CHEMICAL, METALLURGICAL and POLYMER Engineering	*(See below for replacement program)*		
		BEngTech: Materials Engineering in Polymer Technology → *<u>Phase in 2020</u>*	7	3
University of CAPE TOWN	NOTE: Different routes to Materials Engineering, i.e. via *mechanical <u>or</u> chemical* engineering undergraduate programmes + linkage to *materials engineering* (electives in 3rd or 4th years) (Materials Engineering specialisations at post-graduate level.)			
	CHEMICAL Engineering	BSc (Eng) Chemical Engineering (*) → *4-year programme*	8 *	4
	MECHANICAL Engineering	BSc (Eng) Mechanical Engineering (*) → *4-year programme*	8 *	4
	Centre for MATERIALS Engineering (CME) [17] *(Located in the Mechanical Engineering Department)*	<u>Undergraduate Courses (Electives)</u>: • Materials Science in Engineering • Electrical and Mechanical Materials • Materials under stress • Manufacturing with Materials • Materials Science Laboratory Project • Metallic Materials • Ceramic Materials • Polymeric Materials • Composite Materials	(6-7)	1
University of PRETORIA	CHEMICAL Engineering *SARChI Chair in Carbon Technology & MATERIALS* *DST Chair in Fluoro-MATERIALS Science and PROCESS Integration* → *Institute of APPLIED MATERIALS*	NO undergraduate programmes aligned to materials (polymer) science / engineering		
WITS University	CHEMICAL AND METALLURGICAL Engineering	BSc (Eng) in Chemical and Metallurgical Engineering ** *(**) Polymer Science as a core subject*	8	4

2.2.1.2 Post-graduate level

Table 4: Plastics industry-aligned qualification and programme offerings: <u>post-graduate</u> level

[17] Prepares students for registration for research degrees in Materials Engineering at the Master's and ultimately Doctoral levels.

Institution	Department / School	Qualification / program	NQF Level
NELSON MANDELA University	Department of CHEMISTRY	BSc Hons (Chemistry) *[Polymer Chemistry as Elective Module*]	8
		MSc in Polymer Chemistry	9
		PhD in Polymer Chemistry	10
STELLENBOSCH University [18]	Department of CHEMISTRY **and** POLYMER Science [19]	BSc Honours in Polymer Science	8
		MSc in Polymer Science	9
		PhD in Polymer Science	10
TSHWANE University of Technology	Department of CHEMICAL, Metallurgical and POLYMER Engineering	BEngTech Hons (Polymer) → *Phase–in 2021*	8
		[M.Tech and D.Tech in Polymer Technology] → *Being phased out*	*9 & 10*
		MEng (Polymer) → *Phased–in 2017)*	9
		DEng (Polymer) → *Phased–in 2017*	10
University of CAPE TOWN	CHEMICAL Engineering Department	BSc (Honours) in Materials Science → *Aim: To provide one year of intensive training in Materials Science and Technology*	8
	MECHANICAL Engineering Department → *Centre for MATERIALS Engineering (CME)* [20]	MSc (Eng) in Materials Engineering	9
		PhD (Eng) in Materials Engineering	10
University of PRETORIA	Department of CHEMICAL Engineering *SARChI Chair in Carbon Technology & MATERIALS* *DST Chair in Fluoro-MATERIALS Science and PROCESS Integration* ➢ *Institute of APPLIED MATERIALS*	BEngHons (Chemical Engineering) → *Carbon, Fluorine & Polymer Materials as specialisation* [21] → *Core polymer-specific courses:* *(i) Product Design, (ii) Polymer Materials Science, (iii) Polymer Processing, and (iv) Polymer Additive Technology*	8
		BScHons (Applied Science)	8
		MEng (Chemical Engineering) MSc (Applied Science)	9
		DEng (Chemical Engineering)	10
WITS University		PGDip (Eng) Programme	8

[18] Stellenbosch University is the only university that officially offers a Polymer Science undergraduate stream.
[19] The only Chemistry Department in the country that is officially designated as a Department of Chemistry AND Polymer Science
[20] Prepares students for registration for research degrees in Materials Engineering at the Master's and ultimately Doctoral levels.
[21] Core polymer-specific courses: (i) Product Design, (ii) Polymer Materials Science, (iii) Polymer Processing, and (iv) Polymer Additive Technology.

Institution	Department / School	Qualification / program	NQF Level
	School of CHEMICAL and Metallurgical Engineering	→ *Materials Science + Engineering as specialisation*	
		MSc (Eng) Materials Science	9
		PhD (Eng) Materials Science	10

2.2.1.3 Short courses

Table 5: Polymer (plastics) industry-aligned short course provision

HE Institution & Department / School	Courses
NELSON MANDELA UNIVERSITY *CHEMISTRY Department*	A short course in Practical Rubber Technology appears to be the only polymer industry-related course currently on offer. [22]
STELLENBOSCH UNIVERSITY *Department of CHEMISTRY **and** POLYMER SCIENCE*	PRESENT "No, but we want to" – short course provision is currently being (seriously) re-considered. In response to requests from industry. The biggest constraining factors concern practical aspects like timing, contact time required, staffing and costing (return on investment) The thinking at this stage is to offer short courses as modular units which, if compiled or if put together and compiled as a unit, will it eventually lead to the qualification of an Honour's degree. PAST Short courses (two- to three-day duration) were offered on an ad-hoc and company-specific basis (e.g. for Sasol employees). These courses varied in level and focus , from "introducing technical staff to the science of the projects that they are working" to "doing the more advanced courses for engineers and scientists – plant scientists in particular"..
TSHWANE UNIVERSITY OF TECHNOLOGY *Department of Chemical, Metallurgical & POLYMER Engineering*	Provision of industry-relevant short courses supported in principle BUT not doable at present due to issues of physical of human resources and funding. In response to requests from BTech students, a semester bridging subject as part of BTech (running concurrently) focusing on the basics of materials and processing so as to offer students the opportunity to gain more background regarding materials science and processing.
UNIVERSITY OF CAPE TOWN *Chemical Engineering Department* ➢ *Centre for MATERIALS Engineering (CME)*	No current offerings.
UNIVERSITY OF PRETORIA *Department of CHEMICAL Engineering*	PRESENT: Short courses for people from industry as primary target group not currently offered due to "industry funding having dried up". PAST

[22] Source: https://continuingeducation.mandela.ac.za/Other-Courses/

SARChI Chair in Carbon Technology & MATERIALS *DST Chair in Fluoro-MATERIALS Science and PROCESS Integration* → *Institute of APPLIED MATERIALS*	These courses, at post-graduate level – usually one to three-days duration at a cost around R3,000/ day – focused on career-enhancing training in *product development, materials compounding and moulding processes* for *polymer materials* and *plastics components*. *Example* The short course in Polymer Processing and Plastics Product Development provides delegates with an *introduction to plastics as materials, including their development and compounding technology*. The numerous influences of *fillers* and filler–matrix interaction, as well the *machine and process design* are discussed in-depth with a focus on the *design of flame-retardant compounds, polymer modifications, testing and application*. This intensive three-day course is divided into three parts – each with the aim to logically improve delegates' knowledge about *plastics engineering*. The course also gives an overview of shaping processes, with a focus on injection moulding. In-depth process-related properties of plastics, special injection moulding technologies and process chains are also reviewed. *Learning Outcomes:* The objective of this course is to review aspects of the current state of the art in polymer compounding, plastics injection moulding and product engineering. On successful completion of the course, delegates will have the knowledge and understanding to place them in a position to deal with aspects of: • principles of polymer compounding and processing and their effects on morphological structure and properties of manufactured plastic products, and • material and process selection, product design for manufacture, plastics conversion techniques, especially injection moulding and in-mould plastics bonding *Course Content:* • Day 1: Compounding of multiphase plastics • Day 2: Shaping of plastics • Day 3: Processing and product development *Entry Requirements:* Some prior knowledge or experience in the field of *plastics conversion* or *engineering* is recommended. These courses were conducted by internationally-renowned (plastics) polymer industry experts, for example, Prof. Christian Bonten, head of the Institut für Kunststofftechnik (IKT) at the University of Stuttgart in 2010[23]. The expertise of the Institut für Kunststofftechnik comprises the entire field of plastics engineering: material engineering, processing technology and product engineering. Research concentrates on the interaction between material, process and product, in order to improve processability and part properties, intending to create innovative plastic products which are resource efficient and marketable. Research examples: • *Material engineering:* compounding new plastics as well as bioplastics • *Processing technology:* innovative techniques and efficient machines • *Product engineering:* new plastics products, metal substitution, non-destructive part testing

[23] Source: www.uni-stuttgart.de/en/press/experts/Prof.-Dr.-Christian-Bonten

WITS UNIVERSITY *School of Chemical and Metallurgical Engineering*	The *Short Course Unit* of *Wits Enterprise* is responsible for the administration of many Wits University short courses including courses offered to the public as well as short courses which are customised to meet the needs of specific stakeholders. Short courses for the public by the School of Chemical and Metallurgical Engineering are offered at postgraduate level and are run at the same time as a post-graduate course. They are open to anyone who has an interest in that area (industry participants specifically); that is, there are no pre-requisites and they attend at the same time as the postgraduate students do. Advertising occurs by way of putting it on the Wits Enterprise website. The *participants from industry* get a *certificate of attendance* at the course while the *students* get additional reading material that they have to work through, write an *examination* on it and they also have to submit an *assignment or a project* towards a qualification. Attendance runs over a (block) week, from eight o'clock until five o'clock every day. Participants attend lectures and get do various *exercises and calculations* and *are* taken on a *plant visit* one day during the week. **Short course provision for 2019:** ➢ Materials Characterisation (NQF Level 9) *Aims of the course:* The aim of the course is to introduce students to different characterisation techniques that can be critically used to understand material behaviour, failure analysis, and corrosion mechanisms. *Duration:* 10–14 June 2019 *Cost:* R9,900 (TBC) *Course Content:* Materials selected from the following categories: metals, insulators and semiconductors, Polymers and Polymer Composites, Ceramics and ones with interesting surface properties, such as Catalysts. Information needed to characterise each material will be identified and the type of physical interactions needed to obtain this information discussed. The details of the relevant technique will then be given, such as electron microscopy, Raman Scattering, Nuclear Magnetic Resonance, Mass Spectroscopy, Rutherford Backscattering. *Learning Outcomes:* i) Gain an understanding and overview of basic principles of popular materials characterisation techniques and their limitations. ii) Use the skills learned to apply different characterisation techniques in important engineering practices.

2.2.2 Research

Table 6: Plastics industry-aligned research activity and focus areas

INSTITUTION **Dept / School** **Institute / Centre**	**RESEARCH FOCI AND ACTIVITIES**
NELSON MANDELA University *Department of CHEMISTRY*	The Chemistry Department offers postgraduate programmes at Masters (MSc) and Doctorate (PhD) levels in Chemistry. Research in the Department is focused on the following areas: • battery chemistry • POLYMER chemistry • solid state transitions metal ion separation • nanomaterials analytical chemistry • microalgae technologies catalysis • natural products chemistry fuel chemistry • supramolecular chemistry bioinorganic chemistry Research Chair: Professor Paul Watts *Microfluidic Biochemical Processing* Professor Watts' research aim is to develop a *continuous flow methodology* to investigate how small production platforms can enhance chemical manufacture within the South African economy. In addition, research will be undertaken to investigate the integration of synthesis and purification within continuous flow systems.
STELLENBOSCH University [24] *Department of CHEMISTRY AND POLYMER Science* [25]	Fundamental research with practical application – i.e. 'analytical and problem-solving service' to industry The MSc and PhD degree programmes are at the heart of the department's research activities. Students enrolled for these advanced research degrees are required to complete an original research project and thesis in any one of the ***research groups*** of the Department of Chemistry and Polymer Science. These are: 5) Functional polymers, polymer-protein conjugates, functional and dynamic hydrogels *Research leader*: BERT KLUMPERMAN, distinguished Professor of Polymer Science *Research fields:* Polymer chemistry, reversible deactivation radical polymerization, post-polymerization modification, analytical chemistry 6) Advanced analytical polymer science, multidimensional chromatography Research leader: HARALD PASCH, distinguished professor of polymer science *Research fields:* Polymer science, analytical chemistry: • Polymer structure elucidation for structure-property correlations • Comprehensive analysis of industrial polymers • Polymer reaction control and monitoring 7) Polymer structure-property relationship, polymer hybrid materials, polymer nanocomposites and nanofibers *Research leader:* PETER MALLON, Professor of Polymer Science

[24] Stellenbosch University is the only university that officially offers a Polymer Science undergraduate stream.
[25] The only Chemistry Department in the country that is officially designated as a Department of Chemistry AND Polymer Science

	Research Fields: Polymer science, solid-state morphology of complex polymers, polymer nanocomposites and polymer nanofibers 8) Structure–property relationships (polymers) *Research leader:* ALBERT VAN REENEN, Professor of Polymer Science *Research Fields:* Prof van Reenen does a lot of work in structure–property relationships and for the last two decades developed strong partnerships with local industry and specifically Sasol and Safripol, the large polymer producers. His more recent focus is on packaging and food security – smart packaging systems, which he views as "the next big thing".
TSHWANE University of Technology *Department of Chemical, Metallurgical and POLYMER Engineering*	No data obtained
University of CAPE TOWN *CHEMICAL Engineering Department*	*Limited scope (nationally) of research into plastics polymers - Nothing currently at UCT… but could be if funding 'appears'* * At the moment in materials processing [UCT] they are very much focused on metals because – and that is the case at all South African universities – it's about where the money comes from. If you could do research and research is expensive. If you get funding for doing metals research, you do metals research. You are not going to do plastics research. We had someone who did the teaching of the polymers but we could not retain him because there was no fundamental research going on in the plastics area really... we have a philosophy that you can only hire somebody on a permanent basis if you pursued it also as a research arena.
MECHANICAL Engineering Department *Centre for Materials Engineering (CME)* [26]	The Doctoral programme is research (thesis)-based in respect of the following focus areas: • Mechanical Engineering • Engineering Management • Sustainable Energy Engineering • MATERIALS Engineering * • Energy & Development Studies • Engineering Education *(* Through the Centre for Materials Engineering (CME) located in and in close association with the Department of Chemical Engineering.)* UCT Centre for Materials Engineering[27] BACKGROUND The Centre for Materials Engineering has the objectives of *educating and training students in the broad field of materials science and engineering through focused research activities* at BSc(Hons), MSc and PhD levels. At a fundamental level it is concerned with the physical, chemical, electrical and mechanical properties of ceramic, POLYMERIC, metallic and composite MATERIALS and correspondingly developed *appropriate infrastructure and test facilities* to support this activity.

[26] Prepares students for registration for research degrees in Materials Engineering at the Master's and ultimately Doctoral levels.

[27] CONTACT DETAILS: Centre for Materials Engineering, University of Cape Town, Private Bag, Rondebosch 7701. Tel +27 21 6503173 | Fax +27 21 6897571 | Email sarah.george@uct.ac.za (Source: www.mateng.uct.ac.za)

	The Centre's mission is to *use research* as a vehicle to *develop human capacity through postgraduate enrolment* and *promote quality and relevant research through liaison with local and international research partners, industry and government initiatives*. The Centre also provides critical *infrastructure and input to support the thriving mechanical engineering and mechanical and mechatronic engineering undergraduate programmes* that are offered in the Mechanical Engineering Department. RESEARCH The *research activities* of the Centre are aimed at addressing national needs in terms of both the provision of *technological solutions* and the development of *skilled graduates*. *Projects* are directed at an *understanding of the relationships between the production processes, structure, properties and performance of engineering materials*. This encompasses *both applied and fundamental work* on *all groups of materials* with special emphasis on metallic materials and is concerned with the *improvement in the performance of materials* used in engineering systems. The Centre is involved in the *development of new metal alloys, polymers, ceramics and hard materials in co-operation with the materials manufacturing industries*, and the optimum choice of these materials for the mining, marine, agricultural, processing and energy-producing sectors of South Africa. In this way, research undertaken is not constrained by any particular theme, and academic staff are able to initiate new research areas provided that reasonable expertise and appropriate facilities exist. Consequently, *interested parties (both local and international) are encouraged to contact us to discuss collaborative research* in most fields of materials science and engineering *Collaborative Research* The Centre interacts with local industry on various levels to provide solutions related to materials selection, manufacturing and processing, materials specification, and component failure analysis. The well-maintained laboratory infrastructure and in-house expertise enables a comprehensive consultancy service to be offered to industry, where use can be made of a wide range of test and analytical techniques. The Centre is particularly interested in assisting the manufacturing industry and is able to coordinate projects that may involve several aspects of manufacturing, through interaction with related groups in the Faculty of Engineering and the Built Environment at UCT
University of PRETORIA *Department of CHEMICAL Engineering* *Centre of APPLIED MATERIALS*	Research focus "very general" but in regard to POLYMERS it's about *modifying polymers with additives and using polymers as active release, i.e. controlled release systems*. Correspondingly, the focus of research activities span stabilizers, heat stabilizers, pro-degradants, corrosion inhibitors, flame retardants, repellents, and insecticides.
WITS University *School of Chemical and Metallurgical Engineering*	SCOPE AND FOCUS Research is concentrated in these fields and although a strong theoretical tradition is retained, practical research is encouraged. Close liaison is maintained with the Chemical and Mining industries and all means of increasing such contacts are continually being explored. Minerals process engineering enjoys a particularly strong emphasis in this respect. Currently NO plastics (polymer) industry-aligned research activity occurs as "Polymers is the Cinderella in our School" (Head of School) RESEARCH SUPPORT

	The ***Wits Enterprise's Research Support Unit*** acts as an "easily accessible one-stop channel that links the University of the Witwatersrand's (Wits) academics / researchers with the external social and economic world – it helps them source and manage research and consulting services, so as to ensure adherence to relevant University policies and Government legislations, mitigating risk and increasing efficiency. <u>Services</u> currently offered by the Research Support Unit: • review of proposals • budget development • drafting, review and negotiation of contracts • coordination of contractual project deliverables • receipt and disbursement of funds (including foreign currencies) • coordination of client engagement • multi-party project admin • ad hoc contracting of contractors for project • ad hoc contracting of consultants / other 3rd parties • procurement and processing of project expenses • secretarial services (e.g. travel and meeting arrangements) • financial reporting • payment of levies to university in accordance with policies

NOTES:

a) <u>Diploma in Chemical Process Technology (NQF Level 6) at NMU – one of a kind…</u>

This programme is currently the only one of its kind in South Africa. The curriculum has been designed around a comprehensive competency profile for a *chemical process technician*. Hands-on practical training includes training on the only working pilot chemical production facility at a South African university which provides for integration into a real-life working environment.

b) <u>New BEngTech in Materials Engineering in Polymer Technology for TUT</u> (2020 phase-in)

At this time the only National Diploma in Polymer Technology (NQF Level 6) 'remaining in existence' is on offer at NMU, though the historical focus is on rubber industry. As indicated, in 2020 the Tshwane University of Technology will introduce a three-year BEngTech Programme in Materials Engineering in Polymer Technology (NQF Level 7) as replacement for the BTech in Polymer Technology which will be phased out at the end of 2019. Details regarding the programme are as follows:

Programme Overview

The focus of the Bachelor of Engineering Technology in Materials Engineering in Polymer Technology is a "professional qualification and is designed to train polymer engineering technologists who can apply their skills in various occupations to address the advanced technical workforce needs of South Africa.

Career opportunities include the management of:

- production and processing of raw materials
- manufacturing and processing of plastics products
- development, characterisation and quality assurance of raw materials and products
- development of new plastics products and materials

- marketing and sales of raw materials and products

Admission Requirements

- NSC with an endorsement of bachelor's degree or an equivalent qualification; with an achievement of 5 for English, 5 for Maths, and 6 for Physical Sciences, OR
- NC(V) at NQF Level 4 with an achievement of 5 for English, 5 for Maths, and 6 for Physical Sciences / Applied Engineering

Curriculum

Year 1:

Plastics Technology, Organic Chemistry, Strength of Materials, Mechanics, Engineering Mathematics I, Fundamental Skills.

Year 2:

Plastics Conversion, Plastics Part and Tool Design, Thermo-Flow, Plastics Material Science I, Polymer Chemistry, Probability and Statistics, Engineering Mathematics II

Year 3:

Plastics Design Project, Plastics Conversion II, Plastics Material Science II, Thermodynamics, Engineering Practice, and Scientific Computing

c) Stellenbosch University is the only university that officially offers a Polymer Science undergraduate stream.

At all other institutions, entry to polymer/materials science or materials engineering is by way of 'elective' courses associated with BSc(Chemistry) or BScEng (Chemical or Mechanical) – as per example of the undergraduate elective courses in materials/ engineering offered by the Centre for Materials Engineering located at UCT's Department of Mechanical Engineering.

d) Adoption of UK Apprenticeship 'Degree' Model by WITS

Wits University's School of Chemical and Metallurgical Engineering is planning to introduce a qualification based on the Apprenticeship 'Degree' (pitched below degree/ diploma) model in the UK as "they have also had to resolve this discrepancy between the theoretical knowledge and almost a practical materials engineering part – technology, rather, because it's a sub-set of materials engineering". Programme planning and development at this time involves close collaboration between the School and companies in the glass manufacturing industry, but with the intention to extend the programme to any other industry who might be interested. The theoretical training ranges from introductory level to an 'almost on a BTech engineering level' and the program will run over two years, spanning around 10 modules.

In short, the idea is to train up shop floor workers/personnel – who *"understand the steps that they need to do but they don't know WHY the process runs the way it is, why they have to control certain things in the process"* – to a 'reasonably high theoretical level' (BTech) in a particular industry or subject area, following which they will be able to enter the School's postgraduate engineering programmes. The School's representative explains (italicised emphasis by researchers):

> "The idea is also to empower those people to say alright, let's take you through the process – whether it's in a chemical industry, or a materials type industry or a plant that simply processes say pipes or plates of material – and try and give you the necessary theoretical background. And then hopefully, after this the person can connect what he or she is doing on the plant every day … the machinery that they work with, the various parts of the plant with what they have done with us. And that's why we work fairly closely with the plant on this."
>
> "So you have a way to then *couple your theoretical training to a direct plant operation and experience for the learner coming through this process*. And I think something like that, would work well for the polymers industry as well." (Respondent 37, University E)

e) Costs

Tuition fees for Undergraduate studies (BSc, BScEng and BEng) range from around R50,000 to R70,000 per annum whilst Honours programmes average out at around R70,000.

Study fees in respect of Masters and Doctoral programmes (by dissertation) generally amount to R30,000 and R20,000 per annual registration respectively.

However, all HE respondents emphasised the fact that accommodation and travel expenses should be brought into the equation. One respondent costed such expenses at around R80,000 per year.

f) Employment of graduates in the plastics polymer industry

NMMU

Due to the "comprehensive curriculum covered in the National Diploma in Polymer Technology at the Nelson Mandela University…designed in consultation with industry to provide comprehensive broad-based skills", diplomandi reportedly find employment "in all spheres of the polymer industry and wider" (Respondent 33). Locally it will be in the paint industry, rubber industry, motor manufacturing industry and also the plastics industry. The respondent noted a recent case of receiving a query concerning a former student who applied for a project management position at Aspen Pharmacare.

As regards the plastics sub-sector, while some students that find employment (in-service training) in smaller companies, the majority of students reportedly go to Aberdare Cables for in-service training.

University of Pretoria
Students (post-grad) reportedly have no problem finding work – in the chemical engineering field generally – 'because they are very good'. However, many of them head overseas ("sadly").

Stellenbosch University

(Master and PhD graduates Polymer Science)

- Mostly employed in the field of product development QC fields with absorption into management as the only advancement prospect
- Very few graduates (M and PhD polymer science) employed in SMEs or start their own business

- The majority head overseas for career advancement purposes (further studies) – resulting in polymer industry growth being undermined due to insufficient skill absorption

University of Cape Town

"Very few end up in plastics industry, as part of 'bulk chemicals' sector"

The respondent reported that a tracking study on chemical engineering graduates from 2003 to 2008 found that only 4% of graduates ended up in the bulk chemicals sector. 4% - under which the plastics industry resort – whilst between 2009 and 2012 it dropped to about 3%; which translates into three graduates (out of a roughly 100 that graduate annually).

WITS University

No formal tracking system is in place but the respondent reported that it is common knowledge that, in general, 95% of Wits engineering graduates find employment within six months of graduating from university.

g) <u>TVET - HE articulation</u>

No formal collaborative framework is in place with regard to TVET colleges – students who do (not) enter HE studies do so on the basis of meeting specific course entry requirements (or not)

2.2.3 Views of HE respondents on the education and training of engineers and technicians

a) <u>Polymer (plastics) processing/converting industry-weakening demise of erstwhile Technikon-driven "strong technician training programmes"</u>

One higher education respondent decried the demise of the National Diploma in Plastics / Polymer Technology at Technikons as "the biggest disaster that's happened in our tertiary education system in this country" with reference the quality of product produced.

> "Some of the former Technikons had very strong programmes … they were excellent at training people who, shall we say, were immediately useful to the industry. They were taught how to set up an extruder, they did plastics technology, they did six months in an internship… in all ensuring you had an excellent product." (Respondent 34, University B)

Consequently, the critical unfilled knowledge and skills gap in the industry is seen as leaving a detrimental legacy. This impact on the industry is furthermore bemoaned, especially by small to medium-sized converter enterprises.

> "The plastics industry is way back from where it should be because there's not enough people. They don't have the qualified people to drive this industry forward. When you are sitting in our position and you are dealing with industry and you speak with employers and you see what is happening in the small to medium enterprises – the processors, the converters – and you see the problems they come up with and the questions they ask, then you realize there is an enormous knowledge gap and somehow, we need to fill that… whether by way of in-service training, I'm not sure." (ibid.)

In respect to the latter aspect concerning 'filling the gap', the respondent takes issue with replacement of the 'degree-pre-occupied' dispensation that accompanied the ushering in of the Universities of Technology. The respondent castigates the latter for…

> "… training people that are academically not at the same standard as, shall we say, the standing universities but at the same time they have completely lost the technical input, which results in a graduate who is of little value to the industry because of being 'neither an academic nor a technician'." (ibid.)

b) Core purpose and focus of higher level [HE] education and training is about imparting principled knowledge and high-level generic capabilities – value-adding attributes not always sufficiently understood and appreciated industry

HE respondents by and large concurred that in the most broad sense the purpose and focus of higher level [HE] education and training for engineers and scientists, given the diverse industry, is imparting an understanding of central principles governing processes and technology together with high-level analytical or conceptual thinking capability – that is, as opposed to only imparting discipline-specific (specialised) scientific and technical knowledge.

In this regard, one respondent illustrated this educational focus by position by equated reand acquiring skills to be able to 'think things through' – that is, "not just to be able to fix a problem but to analyse and understand why it occurred in the first place; and then to prevent it from happening again.

With reference to problem–solving skills, one respondent illustrated the fundamental difference this position by way of drawing a comparison between an engineer and a technologist (or technician for that matter) in regard to the scope and focus of their work and expertise, whilst at the same time acknowledging the value they both add to operations, albeit in distinctly different ways.

> "In the manufacturing industry they like the technologist because they can be directly – a technologist/ technician you can put to work and you get value from day one almost because they are very hands-on in a day-to-day problem solving way when something goes wrong or breaks down."
>
> "The engineer, on the other hand, is more focused on improving the overall performance of a process, not on a day-to-day basis but when something goes wrong. In such cases the engineer would typically say: "Let me see what actually went wrong" and would then go into depth and say "now we need to maybe do this, then that and then that in order to avoid this going wrong in the future again' …whereas the technologist would typically say: 'let's repair it and we can go on again', with no talk about it happening further down the line."
>
> "Furthermore, if you want to improve on your processes and get more out of them, then you need an engineer." (Respondent 35, University C)

With specific reference to Masters or Doctoral graduates in Polymer Science, another respondent (34, University B) bemoaned a reported tendency by industry employers to focus on the topic of a post-graduate's research theses or field-specific knowledge rather than on their 'generic' or core skills which the respondent views as their 'most valued and useful asset'. What is alluded to is the particular faculty / department's central focus of education and training which is to first and foremost 'develop a fully-rounded person who understands and is part of society, who is a critical or conceptual thinker and problem-solver par excellence and can innovate, when given the opportunity' [paraphrased] – that is, versus merely imparting of disciplinary field-specific specialised knowledge. The respondent's frustration with industry's 'mis-understandings' or lack of appreciation of this view and approach to education and training is bemoaned as follows:

> “I think in many cases the criticisms that industry has of specific degree programmes boils down to questions like: ‘What is the use of this PhD?’, or, ‘What possible relevance does that have?’. And that’s not the point. The point is that this guy can undertake a research program and he understands how to think critically, how to solve problems. Whether he did it on this particular subject or something else, is irrelevant. You point this guy in the right direction and say “This is the problem” and he will solve it for you because he knows how to go about it. And this is something which I don’t think people fully appreciate.” (Respondent 34, University B)

c) <u>Honours/ post-graduate diploma programmes in polymer/ materials science as ‘dedicated’ (current) programme option for both initial engineering training up-training of industry (technicians/ technologists)</u>

The BEngHons (Chemical Engineering) programme at University of Pretoria – with materials science as specialisation – is lauded for its accessibility for industry students as they can do it over two years on a part-time basis; that is, two courses each year instead of four courses full-time. Furthermore, students attend on a block-week basis, which translates into them only missing a maximum of 10 work days per semester. The typical student enrolling for this programme has a BTech in either in either chemical engineering or polymer technology or a BSc degree in chemistry (and physics).

A ‘sad reality’ noted, though, is the fact that the current annual intake only amounts to 15 on average, “though it should be 25…but we don’t get them’”; that is, for economic reasons given that the majority of small and medium-sized companies currently find themselves in survival mode.

Comparatively, the Stellenbosch University respondent bemoaned the fact that the Honours programme in Polymer Science is effectively ‘exclusionary’ as regards industry students as it does not allow for part-time studies.

d) <u>‘Ideal’ plastics industry engineer (disciplinary mix)</u>

One HE respondent, echoing the sentiments of others, views a ‘process engineer with a post-graduate qualification in polymer science’ – that is, either an Honours degree or a Post-Graduate Diploma – to be the “ideal” plastics (convertor) industry engineer (Respondent 34, University B). However, at this particular point, it is currently not possible for process engineers to enrol for the Honours programme in Polymer Science as Chemistry III is an entrance requirement – which process engineers do not have.

e) <u>Lack of/ significant shortfalls in funding is the single-most critical factor impeding teaching and research outputs</u>

HE respondents decried the fact that funding has become a crisis affecting all aspects of provision given the ‘symbiotic relationship’ between teaching and research. One respondent summed it up as follows:

> “Funding has become a huge issue. It is just about non-existent and it’s country wide … a huge, huge problem. You speak to any researcher here, the biggest issue is the research outputs are going down, number of students are going down and the simple reason for that is, there's not enough money to fund these students. Government subsidies to universities have decreased effectively. So it really is an issue. And if any investment needs to be made from the side of industry that is the point at which it must be done.” (Respondent 34, University B)

As teaching at Masters and Doctoral levels is project-based, insufficient funding severely constrains research opportunities for students. One university is dependent on overseas funding.

2.2.4 Industry respondents' views on HE provision for engineers for the plastics industry

a) <u>Usefulness to company of higher education qualifications</u>

Generally

In general, it was reported by industry that there is a significant demand side shortfall in education and training for technicians and engineers in the plastics sector. The study found that post-graduate degrees for polymer scientists and engineers have very limited applicability in industry. Even at the large materials suppliers and producers, who are historically the main employers at a post-graduate level, there has been a significant reduction in post-graduate technical support and employment. However, it was acknowledged that the University of Stellenbosch Polymer Science degree was of direct benefit to industry.

At a University of Technology level, it was also felt that the electrical and mechanical engineering diploma graduates don't have the required knowledge and expertise for the company's technical job requirements. The quality management system courses are viewed in a positive light, but again they lack industry specificity.

Higher Education and a tertiary qualification, whilst lacking industry specialisation is still viewed as beneficial as it establishes a broad knowledge base and encourages critical thinking.

> "But when you are educated, somehow you are able to do the research, you compare the challenges, and you see what is happening out there because your *knowledge is broadened*. So education is very important in a sense that you are *thinking outside the box*." (Respondent 8, HR Administrator, Company D)

> "Though the degree – it's the same everywhere – is fairly *generic* and very little what you study is actually used in industry, the one thing that was good about the Wits degree [Mechanical Engineering] – I can't talk about others – is that they *taught you to think as much as anything else, actually figure out what was happening*." (Respondent 12, Production Manager, Company F).

Polymer Science Degree

From an industry perspective, a Polymer Science degree, as opposed to the Diploma course, addresses principled knowledge of polymers and their construction and physical properties and the implications for analysis and formulations. The degree course with less practical exposure means that there is still *on-the-job expertise that must be acquired*. In general, industry feels that there is a substantial gap in practical expertise that must be obtained *before graduates can add value to a company*. Although, one industry respondent and Higher Education respondents, in general, felt that a strong conceptual base offered by a higher education qualifications prepared graduates sufficiently to pick up the contextual knowledge of the workplace.

> “When you do a degree there’s less in-field work and less practical work. So I think people with degrees often will walk into industry and they still have so much to learn because they haven’t had the in-field experience, but *once they get the gist of all of it they can almost override what they didn’t get and learn and pick it up*.” (Respondent 15, Technical Manager: Production, Company F).

Despite, this generic knowledge baseline afforded by a degree, industry respondents highlighted the *need for plastics sector-focused training at a technical level*, for example knowing how to extrude and do injection moulding and the associated processes and properties. Incidentally, Zimbabwe was cited and commended by a number of respondents as having a strong Polymer Institute and, correspondingly, has resulted in a number of Zimbabweans being employed in the industry and who are lauded for their high levels of (industry-specific) knowledge and skill.

Diploma in Plastics Technology

The Diploma in Plastics Technology content focus is on understanding processes and methods in the plastics industry with a strong technical and procedural knowledge base that is closely aligned with operational work performance. An understanding of the properties of polymers is complimented with industry placement for in-service training, in the form of a practical project. This in-service training is viewed as an important contribution to *understanding the plastics business*, something which a degree would not necessarily offer.

> “The diploma in Plastics Technology is much more hands on, it’s not as theoretical because you don’t go so deep into the theory as you do when doing a degree in polymer science. It’s more about what is the different processing methods; like how do you injection mould, how do you blow mould – the different methods that they would use to make stuff.” (Respondent 15, Technical Manager: Production, Company F)

The perceived target group for the diploma training is viewed as being aligned to *operational functions and middle management*, by virtue of it being more practical and providing a solid knowledge base.

> “I think the diploma level is much more for your people who would be in your quality department, your production managers – so they get a general understanding and a good basis. You can’t define people into boxes, but in general I see Technikon people more at a middle management level in a company.” (Respondent 15, Technical Manager: Production, Company F)

Another respondent lauded the curriculum coverage as ‘perfect’ for ensuring laboratory-ready technologists, with particular reference to the striking a balance between analytical chemistry, polymer chemistry and processes.

> “First year module is analytical chemistry. So this is exactly what you need – this balance between analytical chemistry, polymer chemistry and the processes – how the machines work and how the materials will flow. You need all of that.” (Respondent 1, Technical Manager – Analytical Chemist and Polymer Technologist, Company A)

b) <u>Work-readiness status of new graduates</u>

Link between the science part and the mechanical side missing

Industry highlighted a *lack of understanding of machinery and processes* in new degree and diploma graduates entering the workplace. Whilst graduates have *learned the polymer science and design* aspect, they *lack the mechanical knowledge to complement their theoretical knowledge*. An holistic understanding of the entire production process is needed, from an industry perspective.

The lack of industry shop floor experience is blamed for newly-qualified engineers and polymers scientists being ill-equipped for the workplace and it is suggested that incorporating more practical components into the courses would be beneficial, from an industry perspective.

> “But to try put an industrial engineer there that comes out of varsity on a machine, it’s going to take him a long time to run the machine: he needs to get that practical experience. I don’t know if the varsities could sort of link that somehow, it would be great. Well that’s where they come out ill-equipped. They come out with this wealth of knowledge and everything is ready for them but to physically do it hand-on experience, no go.” (Respondent 4, Manufacturing Manager, Company C)

“Expensive degree” if graduate has no relevant plastics industry exposure / practical experience

This is a particular challenge in the blow-moulding sector, where industry reports it can take years to get familiar with machinery and processes. The complete lack of real world of work experience and understanding from graduates is of deep concern to industry, as it involves long periods of familiarisation on company time and at company cost and they still stand the risk of losing the person afterwards when they are ‘marketable’.

> “I mean X [Polymer Scientist] came in here totally green, I don’t think he had seen a factory. So he is now starting to find his feet after a year and a half. So again you will be investing in him – paying his ‘school fees’ for at least a year, a year-and-a-half until he is prepared for the job. An invariably after those one or two years of training him to get the hands-on experience they are gone – he will be snatched up because he is now really marketable.” (Respondent 4, Manufacturing Manager, Company C)

Another significant issue is the other cost implication for industry because new graduates *expect payment at graduate rates*. However, they do not immediately add value from a production perspective because of their lack of experience and industry must absorb this cost factor for a year or two.

Conceptual thinking ability of graduates compensate for initial lack of operational / practical and process knowledge

Whilst this lack of practical skill is a problem for industry, they acknowledge that it is *compensated for by the conceptual thinking* of engineering graduates. They have *problem solving abilities* and *understand the principles* behind the operation, as opposed to operators.

> "I won't expect an engineer coming from university today who graduated and I give him the machine and say please fix this machine for me by tomorrow. He won't be able to do it. But the way he thinks to approach a problem, is different from the person who is a non-engineer." (Respondent 7, Production Manager, Company D)

This view is mirrored by Higher Education who recognise that an engineer is prepared to deal with improving overall performance of a process and not necessarily handling repairs which are seen as the remit of the technologist or technician.

> "A technologist you can put to work and you get value from day one almost because they are very hands-on in a day-to-day problem solving way when something goes wrong or breaks down."
>
> "The engineer, on the other hand, is more focused on improving the overall performance of a process, not on a day-to-day basis but when something goes wrong. In such cases the engineer would typically say: "Let me see what actually went wrong" and would then go into depth and say "now we need to maybe do this, then that and then that in order to avoid this going wrong in the future again" – whereas the technologist would typically say: "let's repair it and we can go on again**";** with no talk about it happening further down the line." (Respondent 35, University C)

Lack of awareness of the business environment

Industry felt that graduates lack an understanding of the business environment.

c) <u>Unrealistic attitudes and expectations</u>

Industry felt that newly graduated engineers have unrealistic expectations about their competence and promotion prospects, when in fact they need to work their way up the ladder with hands-on experience. Similarly, industry feels that graduates also have unrealistic expectations about their job function and earning capabilities, as discussed earlier. Closely aligned to this point, one respondent also said that graduates have an aversion to internship-based shop floor exposure and learning. Yet industry says this is needed to gain an understanding of process-specific knowledge, machinery and associated core technical skills.

d) <u>Views on the "ideal qualification / knowledge blend" for graduates in the plastic conversion industry</u>

Plastic conversion is about processing which resides in the engineering domain

Due to the plastics converting industry having a strong engineering function dominated by machinery, industry feel that the ideal qualification mix should be a combination of mechanical engineering and polymer science. Whilst chemistry is acknowledged as an important part of the industry, it is not viewed as a central qualification need.

> "So, [a combination of] engineering and polymer science, I would think, would be a better qualification for someone going into the plastics industry – the converting industry." (Respondent 13, Technical Specialist: Production (ex-GM), Company F)

"Turnkey (polymer) scientist"

Fully work-ready polymer scientists familiar with machinery and equipment are cited by one respondent as the ideal solution to graduate provision in the industry.

> "When I run my equipment I chase numbers, I chase efficiencies. So I don't want him spending a year familiarising himself with the machinery and this, that and the other – I want the oke to come in there and start straight away. He has got all this incredible knowledge – he must deliver." (Respondent 4, Manufacturing Manager, Company C)

2.3 Status of Industry–Higher Education collaboration

[NOTE: Suggestions from the respective respondent groups for strengthening collaboration will be considered in the final section.]

2.3.1 Views of Industry Respondents

a) Little / lack of collaboration on the part of Higher Education

In general industry feels that there is *little to no collaboration* with Higher Education institutions. One respondent recalled a time when a University of Technology tried to set up collaborative committees to look at qualifications and curricula, but there was no follow through and the collaboration did not last (Respondent 13, Technical Specialist (ex-GM), Company F)

The lack of collaboration results in *education providers being unaware of what industry does* and this is *reflected in the generic programmes* currently on offer.

> "I just think the training providers need to know what we do. That way they can shape their course to actually address that and not just give a purely mathematical or purely scientific blanket product. I mean they are selling a product, they are selling a skills set." (Respondent 2, HR Manager, Company B)

Despite the current disconnect between industry and higher education, it is felt that a partnership with interested companies and higher education institutions could be beneficial.

b) Formal channels for engaging with Higher Education institutions lacking

Industry respondents bemoaned a reported lack of *formal channels or structures for engagement* with universities – that is, in view of the expressed need to engage with universities to establish what research support they could offer to companies and 'how their systems work'.

In instances, where industry has cited collaboration and engagement with research laboratories and higher education, this has been initiated through individuals' *informal networks* (for example, former students maintaining or re-establishing contact with their teachers) and *word-of-mouth*, as opposed to approaching higher education through formal channels.

c) Intellectual property rights issues regarding collaborative research outputs

With regards to post graduate research outputs there is some concern about agreement on the use of research results by higher education, as the intellectual property resides with the company. This is not seen as insurmountable and would require the signature of confidentiality agreements and structured joint knowledge sharing agreements.

d) Industry-specific training and research institutes are largely lacking in South Africa

Except for the Polymer Science Institute at Stellenbosch University, it was suggested that industry and merSETA should invest in the establishment of an institute in partnership with universities. This is seen as a solution to ensuring enough skilled people are available to industry in the future. It was also suggested that the partnership should be technology focused and collaborative in nature. With multiple stakeholder contributions, including government, it was felt that a high-level partnership with industry and universities could successfully address industry needs.

2.3.2 Views of HE respondents

a) Industrial Advisory Boards as a primary formal structure for engagement with industry

With respect to engineering schools at all universities, industrial advisory boards provide the formal vehicle for obtaining feedback on industry education and training and research support needs.

> "…that's the forum where we get feedback from what is needed in industry. What are the new directions, how do they see us adapting some of our undergraduate or postgraduate structures to accommodate that. So, ja, we do have a mechanism like that." (Respondent 37, University E)

b) Close historical relationships by virtue of having been "born-off' industry

It became clear that all HE institutions have deeply-rooted historical ties with one industry or another which naturally shaped the overall focus of provision. Obvious examples include WITS association with the mining sector, NMU with the rubber industry, and UCT with SASOL and the MQA as main (historical) partners.

The Wits University respondent 'boasted' about an embedded culture of being 'very close to industry', which translates into a strong ethos of demand-driven provision; or, in the words of a representative:

> "Wits has always been a very liberal place in the sense that you are more or less left to your own devices to devise a strategy for needs that you see. But I think, having originated as a mining school, there's always been very much of an awareness of your need to be close to industry. So I would say we are demand-driven to a large extent – probably more so than most other universities are."

c) Ad hoc troubleshooting service as basis for engagement

Historically, by all respondent accounts, engagement with industry has been occurring on an ad-hoc (request) basis, essentially focused on rendering services in respect to trouble-shooting or consulting. However, the scope thereof is reported to have declined significantly in recent years primarily for reasons of economic downturn. Lack of formalisation of such collaboration appears to be a perennial problem.

d) Strong advocacy amongst stakeholders regarding collaboration BUT no substantive action accompanies engagement

Whilst initiatives to bring stakeholders together for engagement in support of collaborative pursuits certainly do not appear to be lacking, one respondent bemoaned the lack of sustained substantive follow-on action which appears to be the inevitable outcome in most instances. The respondent identified two key contributing factors in this regard: (i) diverse, irreconcilable ‘agendas’ ranging from a focus on self-interest to mere survivalism; and (ii) lack of champions to drive and sustain such collaborative initiatives. The respondent explained as follows:

> “Some people are very proactive and very enthusiastic in promoting collaboration and training but somewhere there's a disconnect – everybody talks a good game that we should all do this but as soon as you leave, nobody does anything.
>
> So I think everybody has got their own agenda and I'm not blaming one or the other, it comes from both academia and from the industry and from the board. Everyone has their own problems and their own immediate goals in trying to keep afloat, type of thing… so many of your local industries are just thinking survival.
>
> But ultimately, there isn’t a scope to think a little bit broader and go for it and you don’t have a champion that runs with it, and that I think is the biggest problem. At this time, you need somebody to really take hold of this and say “Okay, this is what we are going to do to pressure the right people, to get the funding, to get the programs set up and get people involved.” (Respondent 34, University B)

e) <u>Partnerships develop and are sustained on the basis of trust relationships between key individuals</u>

One HE respondent, who as head of a chemical engineering department, the research enterprise of which has been funded quite extensively over the last 30-odd years by a particular company, emphasised the critical importance of finding the ‘right partner’ or “trust person” (Respondent 35, University C) – that is, an individual at a prospective company-as-funder. The respondent likens such a pursuit to be ‘almost like a dating game’, though ultimately it boils down to a trust relationship developing between the persons involved. In this case, the respondent is trusted by the company to respect their trade secrets whilst the respondent assists them by way of sharing new insights by virtue of “being on the edge between looking out there and knowing their problems and being in academia”.

3. Suggestions to strengthen the plastics industry, the supply of engineers and technicians in particular

3.1 Views of Industry Respondents

a) <u>Industry-wide and specific training desperately needed</u>

Proactive and specific training is needed at many levels in the plastics industry and the lack thereof is seen as a weakness. However, the industry has a pervasive and entrenched culture of ‘we’ll make a plan’. This culture undermines a systematic and industry needs-driven knowledge and skills development intervention based on solid research.

> “… we desperately need it, it’s a huge weakness in our industry. Sadly it’s something we recognised for a good many years, we just don’t seem to be able to get it right – we are just kind of mulling along. I don’t think the plastics industry will ever die, but it will always be the same old story of ‘we will make a plan’.” (Respondent 13, Technical Specialist – Production (ex GM), Company F)

b) Adopt the German Model

As reported throughout, industry strongly feel that a combination of institutional and workplace education and training is key to preparing industry-ready 'turnkey' graduates. The German model used in the automotive industry is cited as being a solution at university level. German students come out to South Africa for six months of shop floor experience and vice versa, South African engineering students go to Germany for six months.

c) Reinstate a plastics technology diploma

Industry would like to see the introduction of a diploma-level programme at a University of Technology level, not a degree. Ideally this would be specifically designed for the plastics industry with an applied technical base focused on different processes. It should be less science oriented from a polymer perspective and should focus on applied technical aspects of polymers.

> "Also it should be specialised into processes and technologies of plastics sub-industries [sectors] but not necessarily to the level of different machinery details within a sub-sector – like large board extrusion compared to small board extrusion. So the focus should be more generally technical for the different processes – how the blow moulding machines work, how do we fix them and improve them and fault-find … all that type of thing.
>
> On the polymer science side itself, it should not be about in-depth chemistry – rather focus on basics like how do different polymers react, what are the thermostat (sic) for different forms, what are the different additives that you can put onto it and what do they do… and so forth." (Respondent 12, General Manager: Production, Company F)

d) Combine initial Higher Education and Internship-based training

Industry suggests that following a generic degree or diploma course, graduates should do a short internship in a particular sub-sector of the plastics industry. Importantly, the internship should be well-structured and should emphasis critical/conceptual thinking and problem-solving skills particularly with respect to machinery where there is a focus on 'figuring out' the basics, the what how and why of machine workings, assembly and stripping.

Internships are seen as beneficial to all parties. A project-based internship two years into a degree during a summer or winter break, allows students to demonstrate their applied competence, get noticed by industry and potentially then have a job offer on completion of their studies.

> "When they come into the company, you specify to them in the internship what are their projects are and then you carry on with that. Then those projects needed to be submitted. So there, when you have an internship you realise you start picking up people as well." (Respondent 7, Production Manager, Company D)

e) Workplace exposure for students instead of full internship

Rather than a full internship, industry also recommends the benefits of students coming in groups to see the work environment and experience the applied aspects of what they are studying. This could potentially compensate for less than adequate laboratory facilities and machinery at universities. This recommendation is also supported by one Industry Association that currently offers workplace exposure aligned to an industry competition.

f) Higher Education curriculum development and alignment in consultation with industry and informed by research

Respondents suggested that curriculum development at Higher Education institutions should be done in consultation with industry and informed by research and developments in technological trends in industry, in order to stay relevant.

One respondent suggested that Higher Education courses be 'audited' with regard to industry relevance and be amended accordingly in order to graduates to be 'trusted' by industry… "Will I come in with a degree in polyethylene and get work, will I be trusted in the industry with the degree?" (Respondent 8, HR Administrator, Company D)

g) Establishing a highly-visible, multi-sectoral and multi-level skills planning and development pipeline involving all stakeholders and role players

As referenced in focus area three, respondents suggested that a *multi-sectoral and multi-level skills planning and development pipeline* is needed, from artisan to technician to engineer. It would require invested stakeholders to drive it and starting with the Plastics Chamber seems a logical inception point. The initiative would require collaboration with TVETs, Universities of Technology and Universities. Initially the skills development pipeline should focus on the larger plastics sub-sectors in order to demonstrate results. It should also be researched and matched to industry employment needs to ensure people are trained for employment. Lastly a skills planning intervention needs to be widely advertised to industry.

> "Then the other thing that is important is to let industry know about these things; advertise it, market it, so that we know what is there and where to get it…. Because industry will be so excited to say imagine out of that industry is told that there will be ten people qualified in November and these are the lists of those people and you can meet any of them. Send an e mail like that to companies. Before you know it, those people will be invited by companies for an interview." (Respondent 10, HR Manager, Company E)

h) Higher Education institutions to acquire machinery

Industry suggested that education institutions acquire basic plastics sub-sector specific machine for training purposes in support of technical skills development.

i) Through a Plastics Chamber – HE collaboration, develop a broad spectrum and pool of skills catering for the multiple skills needed by all the plastics industry sub-sectors

As discussed above, industry would like to see a systemic, specialised skills intervention catering for all the sub-sectors of the plastics industry. They see a role for the Plastics Chamber to engage with the Higher Education sector on appropriate programs aligned to industry demand.

Industry identifies an opportunity to create an engagement between higher education and industry via the merSETA Plastics Chamber where appropriate qualifications and programs can be offered to meet industry demand. Considering the diversity of the plastics sector; "composites, resins, there's injection, there's blow moulding – and other aspects of plastics" (Respondent 13, Technical Specialist: Production (ex GM), Company F), there is an opportunity to develop a broad spectrum of skills offerings that will meet the multiple skills needed each year in the plastics industry.

At an engineering level, it is suggested, that the Plastics Chamber initiate discussions with higher education institutions to establish what the baseline need is for engineers specialised in the plastics industry. It is further suggested that this be addressed at different levels in a systematic way, in order to create a pipeline. One respondent recommended a pilot project as an opportunity to assess the viability of such a collaborative effort.

A similar suggestion is made at an artisanal level where better partnerships are established to support artisans and to create an opportunity for them to pursue a diploma qualification after having qualified and worked as artisans.

j) <u>Plastics SA Training</u>

Plastics SA are the 'obvious' training partner to industry

Industry perceives Plastics SA as being in close proximity to the skills and education needs for the sector. They have a better understanding than universities and would therefore be a preferred training partner from an industry perspective.

'Doing a good job'

From an operational training perspective, Plastics SA has an extensive focus on machine operations (optimal setting and running) and general plant efficiencies and cost effectiveness. This training is perceived as a valuable contribution to industry.

What is required for them to do it even better?

Industry suggested that a partnership between merSETA and industry, to support Plastics SA and extend the training scope and relevance would be of value. This could be achieved by way of *funding and equipment to develop capacity for workplace relevant training that is sub-sector aligned*. This would assist particularly with getting 'fully fledged' artisans into the industry.

More money needs to be made available for Plastics SA to expand their facilities and *employ the best possible trainers*. If *training was subsidised, it would be more attractive, especially to smaller companies*, and would enhance the industry impact.

> "In short, it is about money: to expand facilities or to employ proper trainers. So it always comes back to money I'm sure. But we know they can offer something that is worth having, whether they are doing it in-house or in their facilities or go to a company." (Respondent 13, Technical Specialist: Production (ex GM), Company F)

k) <u>Provincial specialist training centres required</u>

Ideally, industry would like to see plastics training centres in each province in South Africa, covering all the sub-sectors of the plastics industry.

l) TVET college support

One respondent felt that industry as a whole should support TVET colleges more proactively on an interactive partnership basis. Whilst companies are in competition, the respondent felt that there was benefit in sharing resources and working collaboratively.

m) SASOL

As the major raw materials supplier, industry feels strongly that SASOL should be funding internships “rather than sponsoring sports teams”.

n) Multi-stakeholder initiatives

The value of ‘Plastics Clusters’ was raised and one respondent recalled attempts to establish a Durban metro-driven initiative in plastics. The cluster was to be focused on market information, product use, industry trends and new innovations rather than company competitive issues, however it encountered challenges;

> “I think the KZN fever has got the better of the initiative… they started going to their silos again. But the spirit of getting multi-stakeholders around the table, was there and the need was there. Whether there was enough passion, enough drive, enough budget – I will verify for you.” (Respondent 10, HR Manager, Company E)

o) Advocacy for careers in plastics industry

Industry feels there is a need for the Plastics Chamber to conduct school career awareness programmes for grades ten and eleven, about opportunities in the plastics and polymer industry.

For grade twelve learners considering pursuing engineering as a career, one respondent felt it was vital they be made aware of the commitment and dedication required from a study perspective.

> “When I was doing mechanical engineering, I had seven to eight lectures a day and I had six hours of homework every night. And I struggled a lot. I didn’t go anywhere, I didn’t do anything, I was just studying all the time.” (Respondent 16, Plant Manager, Company G)

p) Optimising and monitoring a development research focus

Industry respondents had numerous suggestions on optimising research opportunities. Firstly, the environmental imperative for recyclable polymers and ‘greener’ replacement materials, creates opportunities for post graduate studies into locally available substitute materials such as wood fibres, sugar cane etc.

Through ‘localisation-focused’ research and development, industry identifies an opportunity to replace expensive imported products and polymers.

> “Plastics industries in South Africa are shrinking in part. There’s a lot of stuff that’s imported. If we brought in the CSIR and the universities and Sasol and say let’s put a group together to steer engineering students’ research projects and theses around products and polymers that we can localise – in a sustainable way.” (Respondent 12, General Manager – Production, Company F)

q) Collaborative research around key plastics engineering problems/challenges

This seen as an opportunity where bi-annually industry could engage with higher education leadership to highlight potential research areas that could add value, for example, "recycling, efficient use of polymers and how to handle laminated paper" (Respondent 10, HR Manager, Company E). It was reported that currently industry is lacking this capacity as they are generally focused on production composition and specifications and are not always focused on environmental requirements. A second respondent similarly highlighted the need for collaborative research around the "5 Rs" of recycling.

r) Optimising the use of university department's equipment and post graduate student resources to solve industry research and development challenges is seen as an opportunity.

> "When I was at [Company] we wanted to do a study on different fillers that we were putting in the test line… and we approached them [HE] to use their equipment. The professor/lecturer was very keen as he had a student who needed to work on a project, we then collaborated like that, which was quite nice because then you as a company get your R&D done and then at the same time, the student gets a project." (Respondent 15, Technical Manager: Production, Company F)

s) Providing a forum, on a regular basis, where universities and students can inform industry about their research focus areas and potential benefits to be derived by industry is viewed as beneficial.

> "As an example, the Plastics Institute, last year organised a national conference where students were given the opportunity to talk about what they were doing and how it supported industry." (Respondent 13, Technical Specialist (ex GM), Company F)

However, it is recognised that industry needs a certain amount of encouragement or coercion to become more involved in keeping abreast of higher education developments and actively highlighting what their needs are. If this could successfully be achieved, it would ensure more applied research outputs that move out of the purely theoretical realm.

t) 'Good' practices promoting company well-being

'International-level' in-house training

'International-level' in-house training is viewed as an effective intervention that ensures high level skills transfer. In the case of internationally owned companies, this type of training is more easily facilitated.

> "He had that department for three years and the skills that he shared, is so, so good. You can see the transformation in the guys, it is happening so well that the people on the floor have received that wholeheartedly and they are running with the whole thing." (Respondent 8, HR Administrator, Company D)

Implementing the Mission-Directed Work Team Concept

The Mission-Directed Work Team Concept is seen as a very good tool which has been influential in the automotive industry but never caught on in the packaging industry. Establishing interactive sessions with customers, for shop-floor personnel, are also used to expand people's understanding of the product and process.

Extensive induction

One respondent cited Unilever's Graduate Recruitment Program as a 'best practice' example of an excellent all-round induction and learning programme geared to the complete work environment and covering all departments and function areas in the company.

> "I went through a Technical Development program, through a Leadership Development program and through a Business Development program. Work-wise the same thing: you start in one department – I started in packaging development – for six months to a year and then you move to the next department for six months a year… and so you move around the company."

'Active' data monitoring and analysis in support of productivity and processing optimisation

Data monitoring and analysis of shop floor production is identified as a fundamental tool for increasing productivity improvement and processing optimisation (running of machines) in one company.

> "Then we started doing the data, gathering the data and it took us a year to build up the whole process look at how we can create productivity and this is how we can build and develop this, how we can build performance. This took us time to make people understand that the performance has nothing to do with the stopping of your machine it just has to do with the running of your machine." (Respondent 7, Production Manager, Company D)

Exposing staff to polymer science basics

In one company, weekly information sessions on polymer science basics have been another effective tool in aiding better job understanding by imparting polymer knowledge at a 'molecular level'. The information sessions are targeted at production personnel, lab technicians ('straight from school') and sales people.

3.2 Views of Industry Association Respondents

a) Relationships

The relationship between industry and higher education is not a simple one and in some instances it is viewed as 'adversarial'. Industry associations play a role in bridging the gap between industry and academia. In the rotational moulding sector, a strong relationship is maintained, as both sides see value to the collaboration of the design competition, and there are further opportunities for mechanical and electrical engineers.

b) Manufacturing exposure

The rotational moulders see great value from plant tours being included in the curriculum and feel that this could be extended to other plastics sub-sectors. The tours expose students to plastic manufacturing processes and encourage curiosity in students.

> "They need to get exposure to the actual manufacturing because that puts it front of mind once again, so they say, 'Oh wow, that's how a coke bottle is made' or 'Oh that's how a dustbin is made' that kind of thing." (Industry Association A)

Beyond curiosity being stimulated in students, the industry feel that this then encourages *design thinking* within the context of plastic processes and understanding the material properties and limitations. The competition prize money encourages students to think of innovative designs that can be industrialised and brings the design and manufacturing interface closer together and introduces a product marketability component.

c) Standards and testing

All three associations' representatives emphasised the importance of standards and testing as a key focus area for consideration – that is, to implement and uphold standards in the industry. An important part of this is *auditing* to ensure *product compliance*, as well as *process compliance*, including *raw materials monitoring* in some instances. In pipe manufacturing there is a reported shortfall in civil engineers' understanding of standards and testing in the pipe industry.

d) Applied research

The three associations had different opinions as to applied research topics that would add value to their sub-sector. One representative felt it was more important to fix the lower level issues first before tackling higher education;

> "You see if you don't get the bottom right, you are not going to get the top right, you know what I mean? If we haven't achieved it at a lower level, Master and Doctoral I don't even have a clue how you are going to improve it. That's pie in the sky at the moment."

Another representative felt that applied academic research was not a "pressure point in the industry" and that industry in-house development with advice from suppliers and "tweaking" was sufficient to address new developments. One association said there was currently virtually no post-graduate research happening.

Areas singled out for possible applied research opportunities were materials science related. Shorter half-life of materials, compostability and bio-degradable properties and organic based stabilisers. The emphasis was on directly relevant post graduate topics for research. One respondent also highlighted the need for collaborative research and full utilisation of different testing equipment, for example, testing facilities in the CSIR that could be adapted to assist the plastics industry. Moving away from a negative silo approach would also stop people working in isolation.

3.3 Views of Higher Education Respondents

a) Two-stream model for post-graduate provision – a Masters and Doctoral (research) stream but also allowing for exit at Honours Level

One respondent decried the fact that universities as essentially training students to become Master's and PhD students (Respondent 34, University B) – that is, instead of creating an opportunity for students to exit at Honours level and get into industry, where there 'clearly is a gap in the market'.

However, it was emphasised that a 'proper' internship program is a requirement for which there has to be funding, which implies buy-in from the companies. It is suggested that local companies could take a student for three months of the year, much like the KTPs (knowledge transfer programs) in Europe.

b) Three-tiered approach to education and training for plastics industry-focused graduates

- Level 1, with a focus on producing Technicians and Technologists (BTech)
- Level 2, with an Honour's level focus targeting 'people knowing chemistry or chemical engineering, but who don't know plastics'.
- Level 3, focused at Masters and PhD levels where students conceptualise projects and test for workability in the laboratory, after which they are employed by industry to develop these projects and processes (up-scale) for eventual commercialisation.

c) Internships

As representing "the only" vehicle for facilitating industry-readiness of (post) graduates 'at no cost to company'. However, lack of interest from companies is bemoaned.

d) Plastics industry RESEARCH CHAIR

One respondent regarded this measure as the most effective and cost-effective model for stimulating / driving effective and cost-effective innovation research in the plastics (polymer) industry. (Respondent 37, University E)

1. Overall discussion, findings and recommendations

Introduction

Having in the foregoing sections presented findings derived from both quantitative and qualitative data as pertaining to the different dimensions of 'engineers and technicians in the plastics industry', the focus now shifts to considering and discussing emerging themes and topics at the level of overall synthesis and interpretation. This will be followed by a consideration of the implications of overall findings formulated by way of recommendations for strengthening the plastics industry generally, and the supply of industry-aligned engineers and technicians in particular.

4.1 Overall discussion and findings

The primary focus of the discussion will be on engineers. However, technicians and technologists presented a very similar theme in the research. It is important to note that the four different respondents (industry, higher education, new graduates and association representatives) have different understandings of the distinction between technicians and engineers. This complexity is further complicated by the conflation of operators/artisans and technicians, particularly by industry respondents. Those in the higher education space are better versed in the distinctions and the concomitant NQF level differentiations.

While the study covered different sub sectors of the plastics industry and these details are contained in the specific findings, it is important to note that the study is focused on the conversion and materials aspect of the plastics industry.

4.1.1 (Graduate) engineers and technicians in the plastics industry

- Do the current by-and-large low levels of employment of engineers (and polymer scientists) speak of an under-appreciation by industry of their potential value-adding capabilities?

> ***Overall Finding 1:***
>
> *With regard to the actual current uptake level of graduate engineers and post-graduates in polymer/ materials science or materials engineering (Masters or Doctoral level), these functionaries are generally not perceived to be 'specifically needed' or deemed essential for company or plant functioning and performance.*
>
> *However, there is evidence of an increasing awareness and appreciation of engineer–technician differentiation in relation to roles or job functions and corresponding value-adding, in respect of principled knowledge and high-level analytical capabilities of engineers in particular.*

As reported under Specific Finding 10 the standout or central theme to emerge from an analysis of demand-side views concerning actual employment (uptake) of graduates or professional engineers in the plastics (convertor and materials) industry is that this occurs on a limited basis only – as was also confirmed by HE respondents – and is largely confined to larger companies characterised by high levels of job function differentiation/ specialisation and having the financial means to employ such functionaries. In the case of small and medium companies, by contrast, a historical trend or phenomenon was noted, where higher-level analysis and trouble-shooting of more complex problems as well as process optimisation interventions is by and large handled by 'old guard' senior managers like managing directors, technical directors and plant/ production managers. Many of the old guard either founded the enterprise or climbed the company ranks over time and take on the traditional 'engineering function'. As a result, they boast intimate and historical knowledge of company machinery, processes and products. However, economic factors also contribute to this trend as the employment of higher-level functionaries, whether engineer or specialist technician/artisan – automated systems and equipment-related in particular – is generally not affordable; resulting in such expertise being contracted-in as and when required (and if affordable at that time).

- Competence and attribute shortfalls of newly-qualified engineers and polymer scientists: a curriculum shortfall issue?

The following key areas of shortfall in knowledge and skill, or gaps in competence and attribute development, were reported by industry respondents in respect of engineers and polymer scientists:

The following shortcomings were reported (high degree of consensus) to be of paramount significance:

a) high-level *analytical and problem-solving skills* due to shortcomings in or conceptual (associative) thinking capability;

b) *interpersonal / people skills and sensitivities and communication skills* which ultimately undermine collaboration and team work capability;

c) *management skills*, with particular relevance to workplaces or plants as business environments; and

d) *'right' attitudes* like willingness to learn (for example, being prepared to be 'subjected' to shop floor learning about processes and machinery under supervision, and guidance by production personnel – that is, as opposed to displaying resentment or resistance by virtue of arrogance or entitlement, with the latter also finding expression in unhappiness with initial remuneration packages.

Interestingly, shortcomings with regard to discipline or study field-specific academic or theoretical knowledge were not fingered in any significant way (that is, in contrast to an 'ideal type' disciplinary knowledge and skills base range and mix, which will be considered below).

Finally, from a work-readiness perspective, lack of sub-sector-specific practical knowledge and experience with regard to core production processes and equipment/ machinery was (predictably) highlighted as the paramount shortcoming – strongly decried in two instances of industry respondents holding strong views about expecting graduates to be 'turn-key' or industry-ready' from day one (of first-time employment) as employers should not be expected to be saddled with the responsibility of 'paying forward' for a period of eighteen months or so before such new employees can 'add value', as required. Conversely, however, the majority of industry respondents expressed compassion for this predicament faced by newly-qualified graduates/ post-graduates citing their principled knowledge base and associated attributes as compensatory features.

The following question now arises: given the key competence and attribute short falls reported by industry (discounting practical knowledge and experience deficits) – that is, essentially relating to non-disciplinary/scientific-specific knowledge, skills/ competences and attributes and indeed non-technical for that matter – does this signify critical curriculum gaps in regard to the relevant qualifications/ programmes at graduate and post-graduate levels?

That these areas of competence are addressed by HE provision, indeed appears to be the case, substantiation for which is derived as follows:

Firstly, HE respondents repeatedly emphasised that these core attributes and capabilities are exactly what the undergraduate and post-graduate programmes seek to address by way of an holistic approach to education and training of engineers.

- *Impart disciplinary and professional knowledge and capability* – i.e. high-level analysis, problem solving and innovative thinking which allows for a 'principled' approach to process optimisation and system or product innovation (design and development).

- *Develop a 'fully-rounded person"* who has awareness of self ('person-hood') and an understanding of interpersonal engagement and sensitivities. Someone who understands and is part of society by way of having an awareness of social and economic environments and the impact of engineering activities on them. Someone who is a critical or conceptual thinker and problem-solver par excellence and can innovate, when given the opportunity'.

[NOTE: paraphrased inputs from one HE respondent in relation to 'undervaluing by industry' of 'core' competences and attributes of engineering graduates, at post-graduate level in particular].

Secondly, an analysis of the respective (stated) programme outlines and learning outcomes and associated competence and attribute development (please refer to Appendix 3) to establish if the above stated education and training aspirations are provided for in terms of curriculum coverage, shows that all the highlighted shortfall areas with regard to competences and attributes are indeed covered in the respective curricula.

All fields of study of the BEng and BScEng degrees have been accredited by the Engineering Council of South Africa (ECSA) and comply with the academic requirements for registration as a professional engineer. The programmes are designed in accordance with the outcomes-based model as required by the South African Qualifications Authority (SAQA). The *learning outcomes* and contents of the programmes have been compiled in accordance with the latest accreditation standards of ECSA, which also comply with the SAQA requirements.

In this regard, a graduate in engineering should be able to apply the following skills "on an advanced level": [28]

Table 7: ECSA-prescribed learning outcomes (generic) for the BEng / BScEng degree:

No.	Learning outcome focus	Competence descriptor
1.	*Problem-solving*	Demonstrate competence to identify, assess, formulate and solve convergent and divergent engineering problems creatively and innovatively
2.	*Application of scientific & engineering knowledge*	Demonstrate competence apply specialist and fundamental knowledge, with specific reference to mathematics, basic sciences and engineering sciences; from first principles to engineering problems.
3.	*Engineering design and synthesis*	Demonstrate competence to perform creative, procedural and non-procedural design and synthesis of components, systems, engineering works, products or processes.
4.	*Investigation, experimen-tation and data analysis*	Demonstrate competence to design and conduct investigations and experiments.
5.	*Engineering methods, skills and tools*	Demonstrate competence to use appropriate engineering methods, skills and tools, including those based on information technology.
6.	*Professional, technical & general communication*	Demonstrate competence to communicate effectively, both orally and in writing, with engineering audiences and the community at large.
7.	*Awareness of impact of engineering activity*	Awareness and knowledge of the *impact of engineering activity* on *social, industrial* and the *physical environments*.
8.	*Being an effective worker*	*Work effectively* on a small project as an *individual*, in *teams* and in *multidisciplinary environments*.
9.	*Life-long learning*	Awareness of the need for lifelong learning and ability to engage in independent learning through well-developed learning skills.

[28] Source:

10.	*Engineering professionalism*	Awareness and knowledge of principles of professional ethics and practice and exercise judgment and take responsibility within limits of competence.
11.	*Engineering management*	Knowledge and understanding of engineering management principles and *economic decision-making*.

In respect of the above, two learning outcomes in particular are critiqued by respondents for lacking the required specificity from an (applied) industry context:

a) *management skills* – project management skills training reportedly lacks a particular plant or workplace-as-*business environment* focus (Respondent 37, University E); and

b) *problem-solving skills* – training being largely focused on root cause analysis falls short by virtue of not also addressing *"problem-solving at the level that your customers of today's world of work require from you"* (Respondent 18, Company G). The respondent, a newly-qualified process engineer employed at a Tier 1 supplier company to the automotive industry, elaborates as follows: *"They don't just want a root cause, they want an AD analysis, they want to see an Ishikawa diagram… they want to see your FMEA. So you have to do specialised training in problem solving, like Six Sigma and so on".*

Complementary Studies courses cover disciplines outside of engineering sciences, basic sciences and mathematics and are split into two categories according to the requirements of ECSA and are essential to: (i) the practice of engineering economics, the impact of technology on society, management and effective communication (as covered above), and (ii) *broaden a student's perspective in the humanities or social sciences to support an understanding of the world*.

As regards the latter category, the course outlines at Cape Town and Pretoria universities are presented below so as to obtain a sense of actual topical coverage.

Table 8: Exemplar course outlines for complementary studies courses in the humanities and social sciences

University of Cape Town	University of Pretoria
This selection involves courses that will *broaden students' capacity to cope with complex social questions that their professional practice will deliver*. These courses also require students to read academic texts and produce extended written responses, usually in the form of essays. The outcomes are also valued by the engineering programme and will build skills that students will take forward in the core courses. Students may select any course for which they meet the admission criteria:	*Perspectives on contemporary society:* An introduction to long-standing *questions about the nature of human societies and contemporary challenges*. Topics discussed include: • globalisation and increasing connectedness; • rising unemployment, inequality and poverty; • rapid urbanisation and the modern city form; • transformations in the nature of work; • environmental degradation and tensions between sustainability and growth; • shifts in global power relations; • the future of the nation-state and supra-national governance structures; and possibilities for extending human rights and democracy *Critical questions* are posed about modern selfhood, sociality, culture and identity against the background of new communications technologies, ever more multicultural societies, enduring gender,

• anthropology, • gender studies, • African studies • history • philosophy • politics • sociology • social infrastructures • film and media studies • archaeology	class and race inequities, and the emergence of new and the resurgence of older forms of social and political identity. These issues are approached from the vantage of our location in southern Africa and the continent, drawing on social science perspectives. *Text, culture and communication:* In this module students are introduced to a variety of texts, including original literary and visual texts, with a view to developing an understanding of how textual meanings have been constructed and negotiated over time. Students are encouraged to understand themselves as products of and participants in these traditions, ideas and values. Appropriate examples are drawn from, among others, the Enlightenment, Modernism, Existentialism, Postmodernism and Post-colonialism.

It would be difficult not to concur that, at a 'normative' and aspirational level, the curriculum scope or coverage in regard to core competences and attribute development, as directed by ECSA-prescriptions, does indeed address, by and large, the very areas of knowledge and skills where industry respondents highlighted shortfalls or gaps as far as newly-employed engineers are concerned (and polymer scientists for that matter). Furthermore, complimentary studies curricula for the courses in the humanities and social sciences (HAS) also quite clearly address the 'rounded person' aspect and corresponding value-adding for work environment functioning, as previously emphasised by one HE respondent, with reference to enhancing interpersonal engagement (sensitivities) or communication and collaboration (team work) capabilities and so forth.

This being the case, why then the widely reported key competence and attribute shortfalls displayed by graduates upon workplace or job-entry – specifically with regard to non-disciplinary and non-technical areas of knowledge and skill pertaining to problem-solving, interpersonal communication and engagement as well as project and people management? In all, this suggests that, in relation to these key learning outcomes, certain factors and circumstances conspire to inhibit the required 'transformative impact' on students from being effected. Various causal factors could be at play but their investigation falls beyond the scope of this study. However, initial 'speculative' thoughts, in combination with respondent perspectives on this matter, could reflect ineffective teaching and learning, students shortcomings in regard to core attributes and aptitudes (cognitive or analytical thinking abilities) as well as motivation or commitment to their studies or particular courses ('complimentary' courses in particular) – the latter arising from selection/ screening and placement processes.

Overall Finding 2:

Apart from sub sector-specific shortcomings with regard to practical knowledge and expertise (a 'logistical' issue preventing on-course practical exposure to current industry machinery), reported areas of knowledge and skill/competence and attribute shortfall or underdevelopment among job entry-level graduate engineers (and polymer scientists) centre on high level analysis and advanced problem solving; contextual process/project management, interpersonal and communication skills, which undermine teamwork capability. Interestingly, shortcomings with regard to disciplinary knowledge were not highlighted.

Analysis of the stated learning outcomes and topical coverage in the relevant undergraduate curricula substantiates a finding that the identified areas of competence and attribute shortcomings are indeed covered in the curricula and therefore represent a curriculum 'uptake' issue (lack of transformative impact) rather than a curriculum 'shortfall' issue. This could be attributed to a number of possible factors, for example, students' shortcomings in regard to core learning-supporting aptitudes and attributes as well as motivation or commitment to studies ('complimentary' courses in particular) due to selection (and placement) processes-related issues, lack of early activation and awareness of the plastic conversion and materials industry in HE programmes, and integrated human capital development interventions.

4.1.2 HE education and training provision for the plastics industry

- ***Scope and relevance to the (plastics) polymer industry of current undergraduate and post-graduate qualifications and programmes***

The focus now shifts to HE qualifications and programme offerings for both the initial education and training of polymer (plastics) industry-focused engineers as well as 'industry upskilling' – that is, with reference to graduate-level education and training opportunities for industry personnel (technologists and technicians).

Against the backdrop of data presented in sub-section 3.1 as well as in Annexure 3 concerning current undergraduate and post-graduate education and training programmes deemed relevant to the (plastics) polymer industry the following overall finding is presented.

Overall Finding 3:

Undergraduate provision is essentially limited to a BEng or BScEng degree in chemical engineering (four-year programmes), represent the 'stock and trade' entry-level programmes – with polymer industry-relevance linkage effected (to the extent that it does occur) by way of student exposure to materials science and processing as core or elective course modules. (Stellenbosch University the only HE institution offering a dedicated under-graduate qualification in polymer science.)

Ultimately, then, specialisation in polymer / materials science and materials engineering/ processing only occurs at the level of post-graduate studies. Whilst honours and/ or post-graduate diploma students are encouraged to pursue (research-based) masters and doctoral level studies, HE respondents share the view that these honours level graduates are ideally equipped for entering industry as well as starting their own entrepreneurial concerns.

Conversely, these self-same honours or post-graduate diploma offerings are also feted as representing the ideal vehicle for upskilling industry personnel who hold a national diploma and BTech in polymer technology specifically. However, the proviso is that enrolment is made possible on a part-time study basis and contact time takes place on a block attendance basis to limit absence from work.

In all, then, a 'materials science and engineering bias' would appear to, by and large, characterise the dominant disciplinary flavour in current HE programme offerings and *research activity in relation to the polymer industry – that is, not also incorporating a mechanical engineering-linked conversion focus.*

According to HE respondents, actual uptake of these 'polymer industry-dedicated' qualifications occurs on a (disappointingly) limited basis, with a critical shortfall in funding for student bursaries for full-time students, as well as a decline in industry demand (linked to economic down turn) cited as the main reasons.

But what is industry's assessment of this current HE provision landscape?

The key themes or issues to emerge from the earlier consideration of industry respondent views on the availability of education and training opportunities for the plastics industry … "too few plastics industry-specific degrees and diploma offerings to cater for industry needs", as noted under Specific Finding 17. This is with respect to initial (post-school) education and training of engineers and technicians, and with specific reference also to formal education and training opportunities for industry-based personnel. As one industry respondent put it:

> "If you look at how many degrees you can do on plastics, it's tiny … only a handful of people go through doing a degree and we don't have enough technology coming into the market." (Respondent 15, Technical Manager–Production, Company F)

Furthermore, post-graduate degrees for polymer scientists and engineers were reported to "have limited applicability in industry". However, it was acknowledged that the University of Stellenbosch's Polymer Science degree was of direct benefit to industry.

Clearly, then, current HE provision for the education and training of engineers, in the view of industry respondents, falls short in delivering the 'plastics industry-designated' engineers specifically required by the conversion sub-sectors. The extent of awareness in industry of the process engineering—polymer science combination qualification at Honours/ Post-Graduate Diploma level, as well as perceptions with regard to relevance, was not assessed. However, an industry perspective is indirectly provided below with respondents' views on the 'ideal qualification', in relation to conversion industry requirements in particular.

- ***An 'ideal' plastics industry-dedicated engineering qualification***

When considering the ideal 'science–engineering' disciplinary mix a qualification should comprise, both HE and industry respondent views share an emphasis on graduates needing to obtain in-depth polymer science knowledge with a knowledge and understanding of 'plastics' in particular – that is, compared to the current broad-based materials or polymer science focus. However, when it comes to the disciplinary focus regarding the engineering dimension, these two respondent groupings by and large part ways, with HE respondents favouring process engineering in contrast to industry respondents emphasising the need for a solid grounding in (sub sector-specific) mechanical engineering or 'machinery knowledge' as well as an 'holistic' understanding of relevant production processes.

These differences in emphasis on the engineering disciplinary mix underpinning an ideal qualification should not be surprising given that the current HE qualifications and programmes and research focus areas, as considered, show a definite bias towards the 'materials side'.

Overall Finding 4:

A graduate-level qualification combining polymer science and mechanical engineering disciplinary knowledge fields together with grounding in conversion sub sector-specific process knowledge is perceived by industry respondents as the IDEAL for the education and training of engineers for the plastics (conversion) industry.

By contrast, HE respondents' views the main tend to favour a qualification comprising a polymer/ materials science–process (chemical) engineering disciplinary blend focused on providing students with a solid grounding in knowledge of 'plastics-specific' science and processing.

- ***Funding shortfall as critical cross-cutting theme impacting on education and training provision and uptake as well as research output***

Overall finding 5:

Increasing 'critical' shortfalls in funding for universities in recent years severely inhibit the capacity of academic departments and research institutes to deliver on all aspects of provision, evidenced in a significant decline in post-graduate student enrolment and, consequently, research activity and outputs; demand for research collaboration and short courses. A reported ''drying up' of funding by industry is bemoaned in particular.

Particularly noteworthy are the following funding-related shortfalls and implications:

- *Obtaining bursary funding for both undergraduate and post-graduate students has become increasingly difficult in recent years – that is, not just for covering tuition fees but also living and travel expenses.*
- *Research funding in respect of post-graduate student enrolment and research projects (Masters and Doctoral level), bearing in mind universities do not receive any government funding for research purposes. Consequently all research projects have to be self-financed by departments/ institutes, which includes bursaries for the post-graduate students, funding for their research projects (anything between R400k to R600k), purchasing and maintenance of research equipment, as well equipment for required for practical training.*
- *Funding for internships for graduates. Funding (from whichever source) of internships for newly-qualified engineers by and large is 'not happening', which holds critical implications for 'growing' sub-sector specific expertise and experience.*
- *Industry demand or support (sending delegates) for short course provision has declined dramatically in recent years with a corresponding decline in offerings as 'minimum' attendance requirements for ensuring presentation cost recovery (including staff contracting) cannot be met. Whilst the ongoing depressed economic climate is fingered as the main contributing factor, part-blame is also laid at the doors of industry bodies with regard to insufficient advocacy for, and facilitation of, industry participation.*

4.1.3 HE–Industry partnerships and collaboration – shortcomings

➢ ***Status of Industry–HE engagement/ collaboration: a case of general disconnect***

With the exception of historical, sector and company specific relationships between certain HE departments, institutes and sector specific companies or bodies, a general disconnect was reported by both constituencies with regards to collaboration. This finding is exacerbated by the geographical location of HE provision which has been driven, in part, by industrial need such as the auto and tyre sector in the Eastern Cape and the mining sector in Gauteng.

The lack of collaboration results in a lack of coherent industry specific training and research institutes in the country and industry respondents felt there were few formal channels to engage with HE and research institutions. HE felt that ad hoc trouble shooting services were one form of engagement, but often the strong advocacy approach of stakeholders results in little substantive action and that strong trust relationships between individuals were critical to the success of partnerships.

With respect to applied academic research, certain industry respondents felt that it is necessary to fix lower level issues first and that supplier advice and inputs would suffice in the interim. Existing testing equipment in institutions such as the CSIR is currently underutilised, but at the same time there was a need to understand the scalability of production from a testing environment to a production environment and that this collaborative aspect was not currently being addressed.

Overall Finding 6:

By respondent accounts it would generally appear that a 'disconnect' characterises the status of industry—HE relations, and, by extension, partnership-driven engagement and collaboration. This is in contrast to some instances of long-established relationships and ongoing cooperation. As consequence, a significant degree of ignorance, if not mis-understanding, concerning the 'other' constituency's offerings and support needs is in evidence, which ultimately results in foreclosure on opportunities for collaboration.

Various strategies and interventions have in the past been adopted for establishing or opening up channels or forums for engagement but these appear to have either failed outright or lacked sustainability in the course of time, leaving informal networking by individuals as the quintessential mode of engagement, to the extent that it actually happens.

This has negatively impacted both industry and HE in different ways and has hindered growth and performance of the sector. It is somewhat ironic as both constituencies appreciate their mutual interdependence but they cannot seem to establish a long-term sustainable collaborative framework that addresses the needs for; relevant research, materials science development, industrialisation of research output, testing facilities and the support needed for standardisation of processes and products.

➢ ***Collaborative research dynamics and issues***

As reported by HE respondents, research collaboration between HE academic departments or research institutes and industry usually originates by either coming up with a concept for testing out or industry approaching the institution with a request for material or product development. For example, one chemical engineering department/associated research institute was reportedly approached by Sasol with a research brief to 'make a plastic out of cellulose'.

However, HE taking a successfully laboratory-tested idea or concept to industry for actual development reportedly by and large presents a struggle, essentially because of a lack of an established culture of close, trust-based working or collaborative relationships between the two constituencies. This results in reticence on industry's part to take up such offers for collaboration including concerns about 'return on investment' and intellectual property rights as possible underlying motives.

One HE respondent put forward his wishes as for an 'ideal model' as follows:

> "We are doing a lot of research, but what's the point if it only ends in those plastic journals etc. – then nobody in South Africa gets benefit out of it. We should be closer to industry. The ideal for me is that when we do a project… once we've developed a concept and made it work in the lab, then industry must take it over and do the final steps. But at the moment this doesn't really happen, so we are forced to work on an almost 'pre-competitive level' because you have big, big problems convincing industry that it works. What would really be ideal, as they do in Germany, is for industry to employ the student to do the actual development [of the tested concept] in industry [with an eye on eventual commercialisation on of the product]." (Respondent 36, University D)

In all, a significant decline in industry-commissioned research is generally reported by HE respondents – excluding, that is, instances of ongoing historically-embedded collaboration.

> ***Overall Finding 7:***
>
> *A general lack of an established culture close, trust-based 'working relationship' between industry and HE institutions inhibits the development and commercialisation of innovative research concepts by HE institutions on a collaborative basis, with industry appearing to be the reluctant partner by and large – in contrast, that is, to the more established ethos of industry approaching HE research institutions with research request or briefs, usually for materials characterisation and development, and/ or product testing as well as any other research or analysis-based trouble shooting.*

4.2 Overall Recommendations

4.2.1 Stimulating the uptake of engineers in the plastics Industry

> ***Overall Recommendation 1:***
>
> *The current low uptake of qualified engineers (at graduate and post-graduate levels) in industry – perceived to stem from a lack of awareness or misunderstanding about their value-adding capability, and lack of sub-sector-specific knowledge and skill – could (in-part) be mitigated through advocacy by industry bodies. The advocacy role would mitigate the lack of awareness and highlight the potential value add of qualified engineers with regard to company functioning and performance by way of the engineers 'generic' value-adding attributes – principled disciplinary knowledge, social and economic understanding*

of the impact of engineering activities, high-level analytical capability and (associated) capacity for critical and innovative thinking.

4.2.2 Enhancing relevance to the plastics industry of HE provision with regard to the education and training of engineers

Overall Recommendation 2:

Current HE provision in regard to the education and training of plastics industry-focused engineers could be strengthened by way of the following interventions:

- *Plastics industry bodies raising awareness and advocating uptake in respect of education and training opportunities at relevant HE institutions*
- *Amending the current 'stock and trade' qualification (at honours/ post-graduate diploma level) comprising a polymer/ material science—process/ materials engineering disciplinary mix to also include a mechanical engineering dimension whilst also reducing the scope of the polymer science component to an exclusive 'plastics knowledge' focus in consultation with ECSA.*
- *Such an undertaking should take the form of a joint venture between the relevant HE institutions and industry stakeholders, with funding, as may be required, provided by industry.*

Overall Recommendation 3:

Enhance world-of work readiness or 'familiarity' of engineering and polymer science graduates by improving the quality and relevance of appropriately equipped practical training facilities at HE institutions in partnership with industry and funding provided by the latter – as well as implementing early industry awareness and activation with undergraduate learners about the opportunities in the plastics industry

4.2.3 Strengthening Industry-HE relations and collaboration

Overall Recommendation 4:

Against the background of the disconnect characterising Industry—HE relations and engagement as well as unsuccessful attempts in the past to establish effective and sustainable modes or mechanisms for engagement and collaboration, industry bodies – Plastics Chamber and Plastics SA in particular – should take the initiative in devising effective ways of engagement that would ensure partnership development and collaboration around mutually-shared concerns, needs and aspirations with the ultimate goal of high-level human capital development for growing an innovative and competitive plastics industry.

4.2.4 Engineering qualifications 'alignment' and substantial funding of industry-relevant HE research activity

Overall Recommendation 5:

In view of the 'insufficiently plastics-focused' shortcomings of current HE qualifications and programmes governing the education and training of engineers for the industry, it is suggested that the Plastics Chamber and Plastics SA assume strong leadership and facilitating roles to effect changes in regard to current provision suggested by industry and HE, in pursuit of developing the 'qualification of ideal disciplinary mix' for ensuring the supply of dedicated plastics industry engineers and scientists.

Conversely, these industry bodies are implored to find creative and substantial ways of alleviating the increasing funding crisis burdening HE institutions, with particular reference to diminishing student uptake at post-graduate levels and a corresponding decline in research activity and output. Efforts to increase the declining uptake of short course provision by industry will go some way to developing a more trusted relationship between HE and industry, as mentioned above. Stimulating multi-dimensional industry funding-related investment and support in these regards should be the first and most critical priority.

Annexures

Annexure 1:
Research Questions (Interview Guides)

merSETA Plastics Chamber Research 2018/19

"What is the shortfall or lack of plastics technicians and plastics engineers in South Africa and what can be done to address the problem?"

INTERVIEW QUESTIONNAIRE

HR Managers

August 2018

I. BACKGROUND

The last research undertaken by the Plastics Chamber (in 2016) comprised a study of innovation culture and capability in the plastics sector. The research followed on but was not directly linked to a three-phased research initiative spanning 2011–2013 which focused on:

- Industry value chains and the mapping of jobs against the Organising Framework for Occupations
- Understanding the size, shape and dynamics of the industry with respect to skills growth scenarios
- How best to attract, develop and retain technical talent

The 2016 study explored innovative practices in the plastics sector within a global context and sought to understand skills and knowledge required to support innovation in the context of "a futures orientation linked to advanced manufacturing".

Against this backdrop an in the light of the well-documented shortage of technicians as well as the lack of preparedness of graduate engineers entering the plastics sector, the Plastics Chamber Task Team in November 2017 suggested a research study be undertaken with a focus on higher education (HE) provision (by universities and universities of technology) to understand what diploma, degree and post-graduate courses are in place and what provision gaps are evident in regard to the specialised skills required by the plastics industry. The study should therefore make recommendations to the merSETA on future HE interventions required that would support emerging areas of competence in the plastics sector.

Correspondingly, one key data collection method involves the conducting of semi-structured (face-to-face) interviews of industry respondents to obtain their views on key aspects concerning skills supply and demand in the plastics industry – in relation to technicians and engineers as well as specialised skills in particular. Four categories of respondents are focused on:

- Engineering department heads and learning programme convenors at HE institutions
- HR and production managers from companies that are representative of the various sub-sectors of the industry
- Newly-employed graduates in the plastics industry (sample companies)
- Representatives of industry associations (sample)

II. BIOGRAPHICAL DETAILS

a) Industry Respondents

<table>
<tr><td>Date</td><td colspan="5"></td></tr>
<tr><td rowspan="3">Respondent</td><td>Name</td><td colspan="4"></td></tr>
<tr><td>Position</td><td colspan="4"></td></tr>
<tr><td>Contact details</td><td colspan="4"></td></tr>
<tr><td rowspan="6">Company</td><td>Name</td><td colspan="4"></td></tr>
<tr><td rowspan="2">Size</td><td>Small*</td><td colspan="2">Medium*</td><td>Large*</td></tr>
<tr><td></td><td colspan="2"></td><td></td></tr>
<tr><td>Core process
(re operations) or
Core service</td><td colspan="4"></td></tr>
<tr><td rowspan="2">Geographical location</td><td colspan="2">Province</td><td colspan="2">Municipality
(metro / district / local)</td></tr>
<tr><td colspan="2"></td><td colspan="2"></td></tr>
</table>

*(*Department of Labour classification criteria: micro/ small = 1 to 49 employees | medium = 50 to 149 employees | large = above150 employees.)*

b) <u>**Industry Association Respondents**</u>

c) <u>**Higher Education Respondents**</u>

III. DISCUSSION

a) Industry Respondents – *HR & Production-linked Managers*

THEME 1:
<u>**Company profile: technicians and engineers**</u>

1. Please provide an outline or ***overview of job titles and functions*** at ***technical*** (operational and maintenance-related) and ***management levels*** (i.e. above intermediate skill or artisanal level) in your company.

2. On what ***basis***, by and large, does ***appointment and promotion*** in relation to these job titles/ functions occur? For example –
   - strictly qualification-driven
   - skills set-driven (including experience)
   - a combination of both (depending on job-level?, job function area?…)
   - other

3. From your experience in industry, please comment on 'entrenched' ***differences across small-medium-large companies*** with regard to:
   - different terminology used in relation to similar job titles/ functions, OR
   - particular job title/ position 'meaning different things', for example, process engineer
   - technician-engineer 'inter-changeability'
   - job-specialisation vs multi-role fulfilling
   - safety compliance/ legislation affecting job title/position

4. Please ***comment*** on the ***accuracy of current OFO Codes*** by way of ***examples*** of any OFO codes that do not align with your company job descriptions.

THEME 2:
<u>**Technicians and engineers in the plastics industry: demand-side shortfall**</u>

5. What ***HE qualifications*** do you think are ***useful/ relevant*** to your company's needs?

6. Generally-speaking, when ***newly-graduated technicians and engineers*** enter the plastics industry/ are *employed* by your company, what in your experience or to your knowledge are their main ***shortcomings*** in respect of ***work or job-readiness***?

a) Technicians
b) Engineers

7. In respect of what ***categories or types*** of ***technicians and engineers*** are the most ***critical shortages*** being experienced?

    a) Technicians
    b) Engineers

8. What ***specialised knowledge and skills*** are your company most critically ***in need of*** and unable to readily source; that is, in relation to technicians and engineers?

9. What ***new or different qualifications/ knowledge and skill sets*** will be required for engineers and technicians in your industry into the ***future***? Why?

THEME 3:
Education and training of technicians and engineers for and in the plastics industry

10. In view of the shortfalls or shortcomings in knowledge and skills of newly-qualified technicians and engineers, as discussed from a plastics industry demand-side perspective, in ***what ways do you think provision by Higher Education (HE) institutions should be adapted so as to improve their work-readiness***? That is, with particular reference to:

    a) *Types of technicians and engineers* ('qualifications vs job title/ function disconnect')
    b) *Scope or content focus of programmes* ("topics") – with regard to both first qualification and advanced studies (specialisation)
    c) *Range of programmes* ("types") – for example, targeted short courses?

11. To what ***extent*** and in what ***ways*** do ***HE institutions collaborate*** with the plastics industry towards alignment of supply and demand?

12. What ***Masters/ Doctoral research topics*** would directly or indirectly benefit you as a company – if at all relevant?

THEME 4:

Suggestions for multi-stakeholder collaborative intervention so as to strengthen the supply of plastics industry-specific (sub-sector) work-ready technicians and engineers

a)
b)
c)

IV. OVERALL COMMENT

NEWLY-EMPLOYED (GRADUATE) ENGINEERS / TECHNICIANS

THEME 1:

Manufacturing sector-aligned education for technicians and engineers working in the Plastics Industry (sub sectors)

1. *When* did you start working at this company, what is your ***job title*** and what are your key ***responsibilities***?
2. What ***qualifications*** do you currently have and where did you complete your education and training?
3. In your opinion, please *rate whether your* ***qualification prepared you for the work place*** in terms of the following areas:

[Rating Scale: 3 = 'strong status' | 2 = 'moderate status' | 1 = 'weak status' | 0 = 'unsure of status']

- theoretical knowledge
- applied knowledge
- practical hands-on skills
- specialist knowledge
- production process knowledge
- problem-solving
- relevant technical language
- operating machinery knowledge
- management skills
- interpersonal skills

4. Being in the workplace now, are there any ***topics*** that you think ***should have been included in your course***? What are they and why do you think they should be included?
5. What ***advanced manufacturing technology*** were you taught in your course?
6. Do you feel your ***lecturers understood the Plastics Industry*** (sub sectors)?
7. What would be the ***next qualification*** you would like to attain and would it be in South Africa or internationally?
8. If you want to ***get promoted*** what will you ***need to do***?

THEME 2:

Workplace requirements and education & training shortfall

9. What are some of the ***things you have learned on the job*** in this company that you never learned at university or university of technology? And do you think ***they can be learned in a formal learning programme, or only "on the job***"? Why?

10. What **t*ypes*** of on the ***job learning*** do you find ***most beneficial***? (mentoring, observation, trial and error, direct instruction)

11. If you did or if you are planning to do a ***Masters or PhD dissertation*** at University can you see a ***direct application of your research in the workplace*** or is there a "***disconnect***"? If there is, what do you think should be done to bring applied research closer to workplace application?

12. What ***skills and knowledge*** do you think will be ***needed in the Plastics Industry*** (sub sectors) in the ***next ten years*** and ***how*** do you think we should ***prepare*** for this requirement in terms of education and training?

OVERALL COMMENT

INDUSTRY ASSOCIATION RESPONDENTS

THEME 1:

Manufacturing sector-aligned education and training for technicians and engineers working in the Plastics Industry (sub sectors)

3. In your opinion, what current *undergraduate and graduate qualifications or programmes* in South Africa facilitate entry for technicians and engineers into the plastics industry (sub sectors)?

4. Do you feel that *generic* technician or engineering *courses* sufficiently prepare graduates to be "work ready" for the plastics industry and why?

5. What *specialised knowledge* do you think is *required* over and above generic education provision and how do you think this should *be taught*?

6. In terms of *global trends* in the plastics industry, what *type of education and training* do you think should be delivered at a technician and engineering level? (e.g. degrees/ short courses/ e-learning/ international skills transfer/mentoring)

Theme 2:

Institutional capacity and collaboration with Industry

7. What do you think *engineering faculties/ departments* should be doing to engage with the plastics industry in respect of demand-side course content and skills development needs?

8. What *critical skills shortages* at technician and engineer levels are highlighted by your members in the Plastics Industry (sub sectors)?

9. Is there a *link* between the level of *production process sophistication* and a *training culture* amongst your members?

10. How does this *differ* between *large and small firms*?

11. Please comment on the *knowledge and expertise needed* in the *whole value chain* of the Plastics Industry and whether it is possible to educate technicians and engineers to meet these requirements in the different sub-sectors of the Plastics Industry.

12. How do you think *applied research* at Masters and Doctoral levels could be optimised to improve industrial application and closer linkages?

13. What *role* do you think *your Association/ Industry body could play to promote collaboration* between the industry and HE institutions to strengthen education and training provision and who do you think should *fund* this collaboration?

THEME 3:
Future skills provision

12. Looking forward 10 years, what *skills shortages* do you foresee at a technical and engineering levels in the Plastics Industry?

13. What are the main *drivers behind these changes* and what do you think industry members should be doing to prepare themselves?

IV. OVERALL COMMENT

14. Any final comments or suggestions about what the *Plastics Industry could do (more or better) to mediate the shortfall* or shortage of technicians and engineers in the Plastics Industry?

Appendix 2:

Letter of Invitation to participate in the research study (Company example)

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merSETA
MANUFACTURING, ENGINEERING AND RELATED SERVICES SETA

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17 October 2018

TO:

Designation:

Name of Company:

Dear ,

INVITATION TO PARTICIPATE IN A RESEARCH STUDY

In light of the shortage of technicians and the lack of preparedness of graduate engineers entering the workplace, the merSETA Plastics Chamber has commissioned a research study which is titled *"What is the shortfall or lack of plastics technicians and plastics engineers in South Africa and what can be done to address the problem?"*

Correspondingly, the focus of this research will be on the current status of education and training provision for the plastics sector at NQF Levels 6 to10 in the Higher Education band (university / university of technology level provision) and the extent to which qualifications and programmes meet (or not) the *specialised* skills required by the plastics industry. The study should make recommendations to the merSETA on future interventions that would support emerging areas of competence in the plastics sector.

Data collection includes both quantitative methods (essentially desktop research-based) and qualitative methods involving semi-structured interviews with plastics industry stakeholders and role-players). Respondents in respect of the latter measure will include learning programme convenors at six universities/ universities of technology; representatives of five industry associations; and human resource and production managers as well as newly-employed graduates (engineers and technicians/ technologists) at 10 companies across plastic industry sub-sectors.

The researchers for this study are Ms Vanessa Davidson and Mr Carel Garisch, both of whom are familiar with the plastics industry makeup and dynamics.

Your company is hereby invited to participate in this research project, as request we hope will be favourably considered as your input will be extremely valuable to us in seeking to address the skills demand-supply disconnect which currently inhibits plastics industry capacity and performance; in regard to higher level skills and specialisation in particular.

If your company is prepared to participate in the research study then we ask you to inform Ms Davidson accordingly at your earliest convenience please. Her contact details are: email vanessa@cobbanconsulting.co.za; mobile 072-836-3998.

Yours sincerely ….

H.M.Morapedi

Hosea Morapedi
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Appendix 3:

Higher Education provision for engineers and polymer scientists: qualifications, programmes, admission requirements, and curricula/ course outlines

1. Nelson Mandela University

1.1 Qualifications and Programmes

UNDERGRADUATE STUDIES

➢ **National Diploma in Polymer Technology (NQF Level 6)**

Programme overview

The Diploma in Polymer Technology is a *three year* programme consisting of two years of full time study and one year Work Integrated Learning (WIL) component, which is carried out in the third year of study. This can be done in any polymer related industry such as the motor-manufacturing and supply - and - service industries, such as paint, tyres and plastics. The *theoretical and practical skills* based training starts with a more general Chemistry, Maths and Physics course to lay the foundation for the more specialized training in the manufacturing techniques, equipment, physical testing and analysis of polymers, rubber compounds and paint formulations. *Practical* training focuses on polymer synthesis, polymer processing techniques such as mixing, callandering, extrusion and injection moulding. Physical, mechanical, rheological and thermal testing of polymers is also carried out. Mechanical testing include tensile, shear, flexural and compression testing whilst physical testing include density, hardness and scratch resistance, to name but a few. These tests ensure polymeric materials meet application performance requirements. Thermal testing of polymeric materials include Differential Scanning Calorimetry (DSC), Thermogravimetric analysis (TGA) for various applications, e.g. specific heat capacity, enthalpy change, crystallinity, melting, vaporization, sublimation, thermal decomposition and temperature stability. This coupled with the Analytical Techniques modules, provides the student with a wide range of analysis methods, including modern instrumental analysis methods such as Gas Chromatographs, Liquid Chromatographs (HPLC), auto-titrators, ultraviolet and infrared spectrometers, atomic absorption and emission spectrometers, for the analysis of a wide range of polymeric products.

Core attributes & skills development

Graduates will develop the following skills during their course of study so as to qualify for entry level positions in supply - and - service industries.

- Perform basic laboratory operations such as weighing, measure precise volumes, heating, transfer solids accurately from one vessel to another etc.
- Using conventional and modern procedures for the quantitative analysis of polymeric products.
- Proficiency in industry standard techniques used in surface coatings, plastics, rubber and related industries.
- Expertise in compiling and processing laboratory/physical test data, writing scientific reports and submitting results using computerized software.
- Following Good Laboratory Practice (GLP), Standard Operating Procedures (SOP), current Good Manufacturing Practices (cGMP) compliance.

Admission requirements

- Admission Points Score (APS) of 34.
- Minimum National Senior Certificate (NSC) requirements for a diploma entry must be met.
- English, Afrikaans or isiXhosa (home language or first additional language) on at least level 3 (40-49%).
- NSC achievement rating of at least 4 (50-59%) for Mathematics.
- NSC achievement rating of at least 4 (50-59%) for Physical Sciences.
- Applicants with an Admission Points Score between 24 and 33 may be referred to write the Access Assessment Test before a decision is made on whether to admit the applicant to the course.
- Students can migrate from Diploma in Analytical Chemistry (2152) to Diploma in Polymer Technology (2234) and vice versa after six months of study, subject to space available in the respective programmes.

Curriculum

YEAR 1 (full time attendance)

- Analytical Chemistry I
- General Chemistry I
- Computer Skills I
- Mathematics I
- Physics I
- Organic Chemistry II
- Paint Technology II
- Polymer Technology II (Rubber and Plastics)
- Polymer Raw Materials II (Rubber and Plastics)

YEAR 2 (full time attendance)

- Polymer Science II
- Polymer Raw Materials III (Rubber and Plastics)
- Paint Technology III
- Polymer Technology III (Rubber and Plastics)
- Analytical Techniques III
- Polymer Science III
- Process Chemistry III
- Practical training forms an integral part of skills development and is presented as separate modules for all subjects.

YEAR 3 (1 year Work Integrated Learning)

- Polymer Production Practice III

➢ Diploma in Analytical Chemistry (NQF Level 6)

Programme overview

The Diploma in Analytical Chemistry is a three year programme designed through consultation with representatives from various Chemical Manufacturing Industries. The programme provides extensive practical training ranging from the classical analytical methods to the more advanced and sophisticated instrumental analysis methods currently employed in the modern chemical industry.

The specialized knowledge and skills based training coupled with the integration of Professional Skills in both theoretical and practical components of the Analytical Chemistry courses provides a solid foundation for the more applied courses given in the second half of the programme. At this stage, students are trained to collect samples and carry out analyses using conventional analytical methods such as Volumetric and Gravimetric Titrimetry whilst observing all sampling, sample preservation, storage and transportation protocols. The more advanced Analytical Chemistry courses focuses on the use of modern instruments such as Gas Chromatographs, Liquid Chromatographs (HPLC), Thermal analysis (TGA, DSC), auto-titrators, ultraviolet and infrared spectrometers, atomic absorption and emission spectrometers, for the analysis of various samples e.g. pharmaceuticals, detergents, foods and beverages, water, etc. This together with training in the use of generic and specialized computer software serves to prepare the student for the Work Integrated Learning (WIL) component which is carried out in their final year of study, in a recognized chemical laboratory; where the skills and knowledge acquired in the two year formal course is applied under real life working conditions.

Students who have successfully completed the Diploma in Analytical Chemistry with an average 60% pass may proceed to the Advanced Diploma in Analytical Chemistry.

Core attributes & skills development

- Perform basic laboratory operations such as weighing, measure precise volumes, heating, transfer solids accurately from one vessel to another, etc.
- Using conventional and modern procedures for the quantitative analysis of organic and inorganic compounds.
- Proficiency in standard techniques used in industry.
- Using qualitative and quantitative methods to analyse various samples.
- Expertise in compiling and processing laboratory data, writing scientific reports and submitting results using computerized software.
- Following Good Laboratory Practice (GLP), Standard Operating Procedures (SOP), current Good Manufacturing Practices (cGMP) compliance as well as respecting workplace hazardous materials information systems (WHMIS) regulations.
- Students also develop skills in effective written and oral communications and develop attitudes and skills required to maintain professional competence beyond graduation.

Admission requirements

- Admission Points Score of 34.
- Minimum National Senior Certificate (NSC) requirements for a diploma must be met.
- English, Afrikaans or isiXhosa (home language or first additional language) on at least level 3 (40-49%).
- NSC achievement rating of at least 4 (50-59%) for Mathematics.
- NSC achievement rating of at least 4 (50-59%) for Physical Sciences.
- Applicants with an Admission Points Score between 24 and 33 may be referred to write the Access Assessment Test before a decision is made on whether to admit the applicant to the course.

Curriculum

YEAR 1

- Analytical Chemistry 1
- General Chemistry 1
- Computer Skills 1
- Mathematics 1
- Physics 1
- Analytical Chemistry 2
- Inorganic Chemistry 2
- Organic Chemistry 2
- Physical Chemistry 2

YEAR 2

- Analytical Chemistry 3A and 3B Theory
- Analytical Chemistry 3A and 3B Practical
- Computer Skills for Analytical Chemistry
- Statistics for Analytical Chemistry
- Introduction to Quality Assurance
- Inorganic Chemistry 3A and 3B
- Organic Chemistry 3A and 3B
- Physical Chemistry 3A and 3B
- Mathematics 2

YEAR 3 (one year Work Integrated Learning)

- Chemical Industry Practical
- Chemical Project

➢ Advanced Diploma in Analytical Chemistry (NQF Level 7)

***Admission requirements**:*
Students who have successfully completed the Diploma in Analytical Chemistry with an average 60% pass may proceed to the Advanced Diploma in Analytical Chemistry.)

Curriculum (one year full time study)

- Advanced Analytical Chemistry 1
- Advanced Analytical Chemistry 2
- Material Chemistry Analysis
- Data Analysis in Chemistry
- Chemical Industrial Control
- Organic Chemistry Analysis
- Sample Handling
- Inorganic/Polymer Chemistry Analysis

➢ <u>Diploma in Chemical Process Technology (NQF Level 6)</u>

Programme overview

The *three-year* diploma course compromises a mixture of *disciplinary-based courses* in chemistry, physics and mathematics together with *integrated disciplinary courses* that combine chemistry, engineering, statistics and computer technology. Apart from the formal course and practical work at Nelson Mandela University's modern laboratories and Chemical Pilot Plant. The programme also includes a *six-month Work Integrated Learning (WIL)* component that must be completed in an *industrial setting* where skills and knowledge acquired at University are integrated and applied under-real life working conditions.

This programme is currently the only one of its kind in South Africa. The *curriculum* has been *designed around a comprehensive competency profile for a chemical process technician* that provides for training in and across *seven competency fields* including personal effectiveness, academic knowledge, professional skills, regulatory knowledge, technical skills, organizational skills and management competencies. *Hands-on practical training* includes training on the *only working pilot chemical production facility at a South African university* which provides for integration into a real-life working environment. Much emphasis is placed on *communication skills and teamwork* in view of the criticality of many of the tasks of the chemical process technician in mega production facilities.

Core attributes and skills development

- Perform start up and shutdown operation procedures.
- Monitoring and sampling or product streams and interpret results coming from the laboratory to ensure that production stays in the correct specifications,
- The graduate will be able to do quantitative statistical process control and discern correctly what action to take in case of sudden pressure or temperature increases or decrease during production.
- The graduate will be able to do critical thinking, problem solving and troubleshooting in the plant to ensure product specifications are met, safety is adhered to at all times and equipment do not suffer any damages.
- Following Good Laboratory Practice (GLP), current Good Manufacturing Practices (cGMP) compliances such as ISO 9001 system and other Quality Management System.

Admission requirements

- Admission Points Score of 34.
- Minimum National Senior Certificate (NSC) requirements for a diploma must be met.
- English and home language on at least level 3 (40-49%).
- NSC achievement rating of at least 4 (50-59%) for Mathematics.
- NSC achievement rating of at least 4 (50-59%) for Physical Sciences.
- Applicants with an Admission Points Score between 28 and 34 may be referred to write the Access Assessment Test before a decision is made on whether to admit the applicant to the course.
- An N3 Certificate with a minimum of 60% in Mathematics and Engineering Science and 50% for any other elective subject to admissions and placement testing.

Curriculum

YEAR 1

- Mathematics I
- General Chemistry
- Introductory Inorganic and Organic Chemistry
- Introductory Physics
- Electromagnetism and Optics
- Essential Computer Skills I
- Professional Skills I
- Introduction to Process Technology
- Basic Process Technology

YEAR 2

- Quality Assurance and Plant Performance
- Applied Computing II
- Professional Skills II
- Physical Process Chemistry
- Routes to Chemicals
- Process Equipment and Operation
- Process Control
- Chemical Process Technology II

YEAR 3

Semester 1

- Chemical Process Technology III
- Process Chemistry III
- Chemical Process Technology Laboratory III

Semester 2 (6 months: WIL)

- Chemical Process Technology Practice

➢ **BSc Chemistry (Major) (NQF Level 7)**

Programme Overview

The Bachelor of Science degree in Chemistry (major) provides a rigorous SCIENTIFIC FOUNDATION in all the major areas of chemistry, namely, Organic Chemistry, Inorganic Chemistry, Physical Chemistry and Analytical Chemistry. Popular combinations with Chemistry are Biochemistry, Botany, Geology, Mathematics, Microbiology, Physics and Zoology. Other BSc majors can be selected from Applied Mathematics, Computer Science and Mathematical Statistics. This degree prepares the graduate for a career in a wide variety of chemically-related areas including, the chemical, petroleum, environmental and pharmaceutical sectors. This fundamental stream also prepares one for a career in academia through studies up to a PhD level.

Students who have successfully completed the Bachelor of Science degree in Chemistry as a major, with an average pass of 60% may proceed to the Bachelor of Science Honours degree programme. This degree programme comprises of core Chemistry modules followed by elective modules in any of the three main fields, namely, Physical / POLYMER, Organic or Analytical / Inorganic Chemistry and conduct a research project in any of the active research areas.

Core attributes and skills development

- Apply one's knowledge and understanding of fundamental concepts, principles and theories to provide solutions to problems in the scientific field, that are both of a qualitative and quantitative nature.
- Recognize, analyse problems of a scientific nature and plan strategies for their solutions.
- Access, evaluate, interpret and synthesize scientific information and data.
- Communicate scientific understanding in writing, orally and using computer software and models.
- Work effectively as a member of a team or group in scientific projects and investigations.
- Apply scientific knowledge and ways of thinking to societal issues, taking into account ethical and cultural considerations.
- Information retrieval skills, in relation to primary and secondary information sources, including information retrieval through online computer searches.

Admission requirements

- Admission Points Score of 40.
- Minimum statutory National Senior Certificate (NSC) requirements for a degree entry must be met.
- English, Afrikaans or isiXhosa (home language or first additional language) on at least level 3(40-49%).
- NSC achievement rating of at least 5 (60-69%) for Mathematics.
- Applicants with an Admission Points Score between 30 and 39 may be referred to write the Access Assessment Test before

Curriculum

<u>First year modules</u>:

- General Chemistry I
- Inorganic Chemistry I
- Organic Chemistry I

<u>Second year modules</u>:

- Analytical Chemistry II
- Inorganic Chemistry II
- Organic Chemistry II
- Physical Chemistry II

<u>Third year modules</u>:

- Inorganic Chemistry III
- Organic Chemistry III
- Physical Chemistry III

POST-GRADUATE STUDIES

➢ BSc Honours (Chemistry) (NQF Level 8)

Programme Overview

Students who have successfully completed the Bachelor of Science degree in Chemistry as a major, with an average pass of 60% may proceed to the Bachelor of Science Honours degree programme. This degree programme comprises of core Chemistry modules followed by elective modules in any of the three main fields, namely, Physical/Polymer, Organic or Analytical/Inorganic Chemistry and conduct a research project in any of the active research areas.

Curriculum

- Analytical science
- General chemistry
- Organic chemistry theory and practical OR,
- Physical / POLYMER chemistry theory and practical OR,
- Inorganic/analytical chemistry

➢ BSc (Honours) Formulation Science (NQF Level 8)

Programme Overview

The degree in BSc (Honours) Formulation Science has been developed to provide the consumer products industries in South Africa with skilled formulators who understand and can apply the theoretical principles of blending various raw materials and active ingredients in different phases to produce stable, homogeneous, and useable consumer products, as well as to develop entrepreneurial skills for the establishment of SMEs.

Formulation Science is concerned with the knowledge and practice of blending and mixing of various components (chemical compounds) in a way that they do not react, but interact to provide a final product with very specific desirable properties or functions. Examples of formulated products include personal care products such as cosmetics; personal hygiene products (soaps, toothpastes, etc.); household chemical products (cleaning agents, polishes, waxes, etc.); pharmaceutical products; processed food products; paints and varnishes; adhesives; industrial chemical products (fuels and lubricants); industrial explosives; mining chemicals; water treatment chemicals and many more.

This unique degree offers in one package, the scientific principles of consumer and industrial product formulation and blending, as well as the practical application in various consumer product industries. It is a multidisciplinary course drawing on various aspects of chemistry, chemical engineering, biochemistry, pharmacy, physics, physiology, statistics, business, etc. A compulsory research project involves the development/formulation of a new product with the goal of possible commercialisation.

Core attributes and skills development

- Technologies and practical skills for the production of formulated consumer products;
- Principles of formulation science to develop new consumer products, improve existing ones, and/or solve formulation problems;
- Advanced experimental design methodologies to design testing protocols for product integrity, stability and efficacy;

- Principles of “mixtures” to design and optimise formulations and blends for specific product properties or actions;
- Regulatory constraints on new consumer product development;
- Principles of technological economics and marketing to evaluate commercial opportunities for new consumer products; and
- New product development protocols.

Masters Programmes: (NQF Level 9)

- MSc (Chemistry),
- MSc (Industrial Chemistry),
- MSc (Nanoscience)

Admission requirements
A BSc Honours degree or an equivalent qualification as determined by committee.

Doctoral Programme: (NQF Level 10)

- PhD (Chemistry)

Admission requirements
MSc (Chemistry) or MSc (Nanoscience)
MSc (Chemistry)
MSc (Industrial Chemistry)
MSc (Nanoscience)
PhD (Chemistry)

2. Stellenbosch University

The Chemistry Department at Stellenbosch University is the only one in the country that is officially designated as a Department of Chemistry AND Polymer Science. The department also plays host to the largest research effort in Polymer Science in the country. It is also the only department at a South African university that officially offers a Polymer Science undergraduate stream – that is, by way of BSc degrees in Chemistry & Polymer Science and Textile & Polymer Science (in 2019/ 2020 the latter is to change to ‘Materials Technology and Polymer Science’).

UNDERGRADUATE STREAM

- **BSc in Chemistry & Polymer Science (NQF Level 7)**

Programme overview
This stream trains graduates in all fundamental aspects of chemistry relevant to all sectors of industry where chemistry or polymer science play a role, whether in manufacturing, sales or research.

Curriculum
YEAR 1:
Introductory Inorganic, Physical and Organic Chemistry; Physics and Mathematics

YEAR 2:
Analytical Chemistry, Inorganic Chemistry, Organic Chemistry, Physical Chemistry
YEAR 3:
Analytical Chemistry, Inorganic Chemistry, Organic Chemistry, Physical Chemistry, POLYMER SCIENCE

- **BSc in Materials Technology (formerly Textile & Polymer Science) (NQF Level 7)**

Programme overview

This stream trains graduates in all fundamental aspects of chemistry and polymer science, and is specifically relevant for careers that focus on the industrial production of materials relevant to the South African industry; or careers in research, focused on technological innovation and materials engineering.

Curriculum

YEAR 1: Introductory Inorganic, Physical and Organic Chemistry, Physics, Mathematics
YEAR 2: Analytical Chemistry, Inorganic and Organic Chemistry, Physical Chemistry, Economics, Business Management
YEAR 3: Polymer Science, Materials Technology, Analytical Chemistry, Inorganic Chemistry, Organic Chemistry, Physical Chemistry

Admission requirements

- Write the National Benchmark Tests AQL and MAT
- Afrikaans or English (Home Language or First Additional Language) 50%
- Mathematics 70%
- Physical Sciences 50%
- Overall average 65% (excluding Life Orientation)

POST–GRADUATE STREAM

- **BSc (Honours) Polymer Science (NQF Level 8)**

The BSc Honours course in Polymer Science is a *full-time one-year course* that commences in January of each year. The course comprises *7 modules*. Of these, 5 are theoretical courses, 1 is a practical techniques course, and the last is a research project. Four of the courses are taken in the first semester, with the other three in the second semester. A breakdown of the courses is provided below.

First Semester

Analytical Techniques (711)

All honours students within the Department of Chemistry and Polymer Science (Chemistry students and Polymer Science students) are required to complete and pass the Analytical Techniques course, which comprises fundamentals of spectroscopy (NMR, FTIR, MS) and chromatography. This course runs for 5 weeks and comprises about 40 contact hours (lectures).

Polymer Science 712 and 724 commence after the Analytical Techniques course. These courses run concurrently. Each of the two courses comprise 40 contact hours of lectures. A list of typical topics that are covered, are given below. Topics may vary from year to year.

Advanced Analytical Polymer Science (Polymer Science 712)

- Introduction and overview
- Characterisation and analysis of polymer surfaces and microscopy
- Chromatography as a tool for polymer analysis
- Mass Spectrometry of Polymers
- Thermal analysis
- Spectroscopic analysis
- Analysis of polyolefins
- Morphology and physical properties

Polymer Chemistry (Polymer Science 724)

- Introduction to polymers as materials; applications and the scope of the science
- Polymerisation conditions and methods
- Free radical polymerisation chemistry and kinetics
- Controlled radical polymerization reactions and the application to complex polymer architectures
- Stepwise polymerisation: chemistry, kinetics and polymers
- Catalysis: transition metal catalysts, processes and polymers
- Ionic polymerization techniques and polymers
- Polymer degradation and stabilisation
- Industrial applications of polymer synthesis: Overview of processes and polymers
- Special topics: *e.g.* water soluble polymers, high temperature resistant polymers

Practical techniques (Polymer Science 713)

This is a 5-week course during which time students will master *practical techniques that are relevant to the field of synthetic polymer chemistry*. Students are required to spend about 16 – 20 hours per week in the laboratory. This course overlaps with the Polymer Science 714 and 724 courses.

SECOND SEMESTER

Physical Polymer Science (Polymer Science 744)

The following topics are covered. The course comprises about 20 2-hour lectures (40 contact hours)

- Polymers in solution
- Elasticity and plasticity
- Viscous flow
- Rubber elasticity
- Phase transitions, thermal transitions
- Viscous flow and deformation and fracture phenomena in the melt
- Fracture and failure
- Short-and long term effects
- Fatigue, environmental effects and impact properties
- The theory of particulate and fibrous reinforcement
- Polymer crystallisation
- Block copolymer phase behaviour in bulk and in selective solvents

General Polymer Science & Special Topics (Polymer Science 754)

The following topics are examples of what could be covered. This course runs concurrently with Polymer Science 744. The course comprises about 40 contact hours.

- Raw materials and raw material production in South Africa
- Processing: compounding, extrusion, injection moulding and blow moulding
- Elastomer technology
- Polymeric products: Adhesives, paints, foams, industrial textiles
- Polymer blends and composites
- Nanocomposites
- Biomedical applications of polymers

The above module also involves visits to local industries.

Research Project (Polymer Science 714)

Each student will complete a research project during the second semester. Students will be given a list of research topics to select from at the end of the first semester. Research will be undertaken under the supervision of an academic staff member, with mentorship of senior postgraduate students. Each honours student will therefore be assigned to a specific research laboratory for the second semester. Upon completion of the project, each student will be required to present his/her results to the faculty and students of the Department of Chemistry and Polymer Science. A written report, in the form of a short research publication, is also required.

Masters and Doctoral Programmes

The MSc and PhD degree programmes are at the heart of the department's research activities. Students enrolled for these advanced research degrees are required to complete an original research project and thesis in any one of the research groups of the Department of Chemistry and Polymer Science.

The following degrees are offered:

- MSc in Chemistry
- MSc in POLYMER Science
- PhD in Chemistry
- PhD in Polymer Science

Admission requirements

- For MSc: an appropriate BSc Hons degree or equivalent qualification
- For PhD: an appropriate MSc degree or equivalent qualification

3. Tshwane University of Technology

(Department of Chemical, Metallurgical and Polymer Engineering)

UNDERGRADUATE / DIPLOMA STREAM

➢ **BTech: Polymer Technology [29] (NQF Level 7)**

Admission requirements:
National Diploma: Polymer Technology / National Diploma: Engineering (Chemical, or Mechanical, or Metallurgy) / National Diploma: Analytical Chemistry

OR
A NQF Level 6 Bachelor's Degree in Chemical/Mechanical Engineering (or a closely related field) obtained from a South African university.

Curriculum:
First Semester

- *Polymer Technology: Practical IV*
- *Polymer Technology IV*

  This subject comprises compulsory, as well as free-choice, subject matter. Compulsory subject matter includes the selection of polymers and mix design, chemical technology of fluid systems, cellular polymers, polymer films, textiles, polymer morphology, polymer structural analysis.

Second Semester

- *Polymer Science: Practical IV (year subject)*
- *Polymer Science IV*

  There are two components, namely Polymer Chemistry and Polymer Physics. Polymer Chemistry examines the bond between the chain structure, morphology, microstructure and the solvability and molecular mass. Speciality polymer, cross-bonding reactions and the mechanism of degradation and protection against degradation are also examined.

➢ **Bachelor of Engineering Technology (BEngTech) in Materials Engineering in Polymer Technology (NQF Level 7)**

[2020 phase in – as replacement for BTech: Polymer Technology]

Programme overview
The focus of the Bachelor of Engineering Technology in Materials Engineering in Polymer Technology is a professional qualification and is designed to train polymer engineering technologists who can apply their skills in various occupations to address the advanced technical workforce needs of South Africa.

Career opportunities include the management of:

- production and processing of raw materials
- manufacturing and processing of plastics products

[29] To be phased out at end of 2019. [To be replaced by Bachelor of Engineering Technology (BEngTech): Materials Engineering in Polymer Technology – 2020 phase in]

- development, characterisation and quality assurance of raw materials and products
- development of new plastics products and materials
- marketing and sales of raw materials and products

Admission requirements:
NSC with an endorsement of bachelor's degree or an equivalent qualification; with an achievement of 5 for English, 5 for Maths, and 6 for Physical Sciences OR NC(V) at NQF Level 4.with an achievement of 5 for English, 5 for Maths, and 6 for Physical Sciences / Applied Engineering

Curriculum

YEAR 1:

- Plastics technology
- Organic chemistry
- Strength of materials
- Mechanics
- Engineering mathematics I
- Fundamental skills

YEAR 2:

- Plastics conversion
- Plastics part and tool design
- Thermo-flow
- Plastics material science I
- Polymer chemistry
- Probability and statistics
- Engineering mathematics II

YEAR 3:

- Plastics design project
- Plastics conversion II
- Plastics material science II
- Thermodynamics
- Engineering practice
- Scientific computing

POST-GRADUATE STREAM

[M.Tech and D.Tech programmes in Polymer Technology in the process of being phased out.]

➢ **Master of Engineering: Polymer Technology (NQF Level 9)**

Duration:
A minimum of one year and a maximum of three years.

Admission requirements:
A Baccalaureus Technologiae in Polymer Technology, or a Bachelor of Engineering in Polymer, OR a Bachelor of Engineering Technology Honours in Polymer Engineering, OR a Bachelor of Science in

Engineering in Materials Engineering/Polymer Engineering/Plastics Technology/Polymer Sciences or related field, obtained from a South African university, with an aggregate of 60% for the final-year of study.

Candidates with a baccalaureus technologiae will be required to complete bridging modules: Engineering Data Analysis, Research Methodology and Systems Modelling (or their equivalents) at NQF Level 8. Candidates who have not completed these bridging modules before registration, will be required to complete them concurrently with this qualification.

Holders of any other equivalent South African or international qualification may also be considered,

Curriculum
Dissertation: Engineering Polymer Technology

- **<u>Doctor of Engineering (D.Eng): Chemical (NQF Level 10)</u>**

Admission requirements

A Magister Technologiae: Engineering, or Master of Engineering, or a master's degree at NQF Level 9 in a related field, obtained from a South African university.

Holders of any other equivalent South African or international qualification may also be considered, see Chapter 1 of Students' Rules and Regulations.

Curriculum

OPTION 1: Thesis: Engineering: *Chemical*
OPTION 2: Thesis: Engineering: *Materials*
OPTION 3: Thesis: Engineering: *Metallurgical*
OPTION 4: Thesis: Engineering: *POLYMER TECHNOLOGY*

4. University of Cape Town

Different routes, i.e. via *mechanical* <u>or</u> *chemical* engineering undergraduate programmes + linkage to ***materials engineering*** (electives in 3rd or 4th years) as well as at post-graduate level.

> We have a four-year degree and then in third and fourth year, we have that linkage into materials engineering. So our students here, they do not do the full materials engineering part, they do selected courses in materials and engineering. In Master's they can do pure materials engineering or whatever the students would like but that's where they can then specialise, yes.

<u>UNDERGRADUATE STUDIES</u>

Department of CHEMICAL Engineering

- **<u>BSc in Chemical Engineering</u>**

Programme overview

The ***four-year*** *undergraduate degree* prepares graduates for <u>careers</u> in the chemical, metallurgical, and PROCESS industries, and is fully accredited by the Engineering Council of South Africa. There is a limited amount of specialisation in the areas of minerals processing, bioprocess engineering, catalytic processing, and environmental process engineering.

Core attributes and skills development

The programme focuses on developing technical expertise, problem-solving, teamwork and communication skills. Practical, hands-on learning is a thread that runs through all four years of the undergraduate programme.

Under the guidance of an academic, students work on practical assignments where questions are open ended and probing, requiring the need for observation and reasoning to develop a working understanding of the underlying phenomena.

Admission requirements

Admission to the undergraduate programme is based on a 'points' system calculated on applicants' matric exam results and National Benchmark Test (NBT) results. A minimum requirement of 80% for mathematics and 70% for physical sciences is applicable to all applicants.

There is an extended degree through the Academic Support Programme (ASPECT). This is an extended five-year degree programme which provides extra support in the first year, where a lighter load of courses is taken. Entry into this programme is possible after the first set of evaluations half way the first semester and after the mid-year exams.

Curriculum outline

Core courses

In the core chemical engineering courses students are taught fundamental theory, structured into a coherent sequence. Project work is incorporated throughout the programme to allow for the building of crucial engineering skills in the areas of environment and economics, safety and health, communication drawing and computing.

In each of the first three years of the programme there is one full year chemical engineering course (CHE1005W, CHE2005W and CHE3005W). The fourth year comprises two closely linked first semester courses taught in blocks, followed by the design and research project courses in the second semester.

Elective courses

Elective courses in advanced engineering, including a suite of courses linked to research specialities in chemical engineering, are taken from the third year onwards.

Science Courses

The core Science Courses in the programme comprises

- first and second year Engineering Mathematics,
- first year Chemistry,
- first year semester course in Physics (focusing on mechanics),
- first year semester course in Statistics

From the second year students need to elect one of the following courses:

- Chemical Sciences
- Mineralogical Sciences
- Biological Sciences

Humanities and Other Courses

Students are required to choose electives in the following categories:

i) Language elective (18 credits)

Students are required to do any language course at UCT that will give them exposure to a language other than English that they do not already speak at this level.
Most students will select from the intensive courses that are offered at first level, but students may alternatively select to study at the second level course a language they have previously studied at school.

ii) Humanities selection (18 credits)

This selection involves courses that will broaden students' capacity to cope with complex social questions that their professional practice will deliver. These courses will also require students to read academic texts and produce extended written responses, usually in the form of essays. These are outcomes that are also valued by the engineering programme and will build skills that students will take forward in the core courses. Students may select any course for which they meet the admission criteria:

- Anthropology, Gender Studies, African Studies
- History
- Philosophy
- Politics
- Sociology
- Social Infrastructures
- Film and Media studies
- Archaeology

iii) Free elective (16 credits)

Students may do any course at UCT for which they meet the prerequisites, and where they haven't already covered that content in another course.

POST-GRADUATE STUDIES

Department of CHEMICAL Engineering

The department has dynamic research programmes and students who have obtained satisfactory results in their undergraduate courses are encouraged to return for postgraduate study. Postgraduates may register as Masters or PhD students. The purpose of the MSc degree is to master the scientific method, with emphasis on critical evaluation of all information and data. The purpose of the PhD degree is to develop new insights in the field of Chemical Engineering. Both the MSc degree and the PhD degree incorporate the planning and execution of a research project within a particular time frame.

Masters and Doctoral Programmes

Masters

There are two routes available for achieving a Masters degree: a student may register for a full research Masters or take a coursework Masters degree in one of the following areas –

- bioprocess engineering
- catalytic process engineering
- hydrometallurgical engineering

Minimum admission requirements

A person shall not be admitted as a candidate for the degree unless he or she is proficient in English and –

a. is a graduate of the Faculty or of an engineering or geomatics programme of any other university recognized for the purpose; or

b. holds an appropriate BSc(Hons) degree; or

c. holds an approved three-year degree and (i) who has a minimum of five years' experience relevant to the field in which he/she proposes to study, or (ii) who in addition to the standard programme requirement first completes a minimum of 144 credits of approved coursework; or

d. has passed at any university or institution recognized for the purpose, such examinations as are, in the opinion of the Senate, equivalent to the examinations prescribed for the degree of BSc(Eng) or BSc(Geomatics) at the University; or has in any other manner attained a level of competence which in the opinion of Senate on the recommendation of the Faculty, is adequate for the purpose of admission as a candidate for the degree

➢ MSc in Engineering specialising in Bioprocess Engineering (NQF Level 9)

Core courses

- Dissertation Preparation (in 1st year)
- Dissertation Chemical Engineering
- Microbial Physiology & Dynamics
- Advanced Bioprocess Engineering
- Chemical Engineering Topics for Scientists
- Biotechnology Laboratory
- Research Communication & Methodology
- Master's Journal Paper

➢ MSc in Engineering specialising in Catalysis and Catalytic Processing (NQF Level 9)

Core courses

- Dissertation Chemical Engineering
- Introduction to Heterogeneous Catalysis Research
- Characterisation Techniques for Catalysis Research
- Research Communication & Methodology
- Dissertation Preparation
- Master's journal paper

PhD

Doctoral degrees are always ***full-time research programmes***, and can be taken in any of the ***departmental research interest areas***, *viz*:

- bioprocess engineering
- catalysis
- minerals processing
- hydrometallurgy
- environmental engineering
- crystallization and precipitation
- chemical engineering education

Department of Mechanical Engineering

UNDERGRADUATE STUDIES

➢ **Bachelor of Science in Engineering in Mechanical Engineering**

[BSc(Engineering)(Mechanical Engineering)]

The Mechanical Engineering curriculum is structured to provide students with a fundamental understanding of solid mechanics, dynamics, thermodynamics, fluid mechanics and materials, which is conveyed via formal lectures, experimental investigations, laboratory sessions and the solving of structured problem sets. Engineering design is made central to the curriculum and thus forms the core of the programme. The discipline integrates content from other mechanical engineering courses with design philosophies and best practices and develops both team and individual skills.

Curriculum
Core courses
YEAR 1

- Chemistry for Engineers
- Mathematics IA for Engineers
- Mathematics IB for Engineers
- Introduction to Engineering Mechanics
  Course outline:
  This course aims to introduce students to the concepts of engineering mechanics. It develops the concept of equilibrium of particles and rigid bodies which is a required basis for solving engineering problems in mechanical engineering and cognate disciplines. The course reviews the use of vectors for displacement, position and force. Students will learn how to represent engineering problems using free body diagrams and graphical methods. Forces considered are applied as point loads, moments and distributed loads. Internal resultant forces that occur due to axial loading, bending and torsion will be considered. Applications include statically determinate systems only: basic trusses, beams, frames and machines. Concepts of centroids, second moment of area, parallel axis theorem and mass moment of inertia are covered. Elementary solid mechanics ideas such as stress, strain and simple mechanical properties of materials are also introduced.

- Introduction to Mechanical Engineering

  Course outline:

  This course provides students with a broad introduction to mechanical engineering through a variety of activities culminating in a competitive group design challenge. Throughout the course, students will engage with classical mechanical engineering concepts, participate in experiential activities, and locate what they are learning through the use of case studies. Topics covered include what it means to be an engineer; how to use effective oral, written, and technical communication; the interrelationship between technology and society; professional ethics; the need for sustainable engineering activities; the engineering design process; forces in structures and machines; thermal and energy systems; motion and power transmission; fluids engineering; basic electrical theory and materials and stresses.

- Introduction to Engineering Drawing

  Course outline:

  This course has been structured to introduce the basic drawing principles for students who have no prior drawing experience. It also aims to provide the relevant drawing and design knowledge to enter the design stream of the Mechanical Engineering degree. Drawing equipment is used to convey the principles of descriptive geometry and drawing standards. Free hand sketching is taught to interpret orthographic and pictorial projection and basic design principles. The primary focus of the course is the generation of orthographic working drawings for the manufacturing environment.

- Introduction to Mechanical Design

  Course outline:

  This course aims to form a foundation of drawing and design using 3D Computer Aided Drawing software. The software will be a used as a tool to generate and interpret drawings for a manufacturing environment. Basic fundamentals of mechanical engineering design will be applied using free hand sketching skills and 3D CAD. Topics include: Solid modelling applications with design intent; fits and tolerances; detailing for manufacturing; interpretation of drawings; and assembly design for manufacturing.

- Physics A for Engineers
- Physics B for Engineers
- Practical Training I

  Course outline:

  This opportunity for practical experience for Electro-Mechanical and Mechanical Engineering students culminates in a certificate showing evidence of completion of suitable work in basic workshop processes during a period of at least four weeks in an approved industrial workshop. The practical experience should be gained in the mid-year or end of year vacation following the year of first registration in the Faculty. The evidence of completion must be submitted by 31 March of the following year. Alternatively students may produce a certificate showing evidence of completion of an approved structured intensive two-week practical training course (e.g. at a University of Technology). Students are required to cover at least the following: *welding, turning, and basic fitting*.

YEAR 2

- Introduction to Programming
- Introduction to Electrical Engineering
- Introduction to Electronic Engineering
- Vector Calculus for Engineers
- Linear Algebra and DEs for Engineers
- Thermo-fluids I
- Dynamics I
- Mechanical Engineering Machine Element Design I
- Mechanics of Solids I
- Materials Science in Engineering
- Practical Training II

YEAR 3

- Energy Conversion & Utilization
- Project Management
- Mechanics of Solids II
- Dynamics II
- Thermofluids II
- Professional Communication Studies
- Thermofluids III
- Experimental Methods
- Mechanical Engineering Machine Element Design II
- Mechanical Engineering Machine Element Design III
- Materials Under Stress
- Production Processes
- Statistics for Engineers

YEAR 4

- Mechanical Vibrations
- Industrial Ecology
- Product Design
- Manufacturing and Nanotechnology
- Fundamentals of Control Systems
- System Design
- Engineering Professionalism
- Final-Year Project

*Elective Core Courses – s*tudents must select one of the following courses:

- Numerical Methods in Heat and Fluid Flow
- Finite Element Analysis
- Heat Transfer and Psychrometry

**Elective Complementary Studies Courses*

Complementary Studies courses cover disciplines outside of engineering sciences, basic sciences and mathematics and are split into two categories according to the requirements of ECSA:

a) are essential to the practice of engineering economics, the impact of technology on society, management and effective communication, and
b) broaden a student's perspective in the humanities or social sciences to support an understanding of the world.

Students must select at least 18 credits worth of courses which fulfil the requirements of category (b).

➢ **Bachelor of Science (Honours) in Materials Science (NQF Level 8)**

The Department offers a BSc(Hons) in Materials Science to graduates with a three-year Bachelor of Science degree. The aim is to provide one year of intensive training in Materials Science and Technology. The broad-based instructional approach prepares graduates for careers in a wide range of industrial settings, from small manufacturing companies to large corporations producing bulk commodity products, and R&D laboratories. In addition the BSc(Hons) in Materials Science programme prepares students for registration for research degrees in Materials Engineering at the Master's and ultimately Doctoral levels.

The programme runs over one year, with students taking a structured programme of 144 credits of coursework, including a project, as follows.

Core Courses

- Materials Science Honours Research Project
- Manufacture & Properties of Composites
- Manufacture & Properties of Ceramics
- Properties & Manufacture of Metallic Materials
- Manufacture & Properties of POLYMERS
- Experimental Techniques in Materials Science

Elective Courses

- Mineral and Metallurgical Processing
- Materials under Stress
- Production Processes
- Manufacturing with Materials
- Phase Transformations in Materials
- Professional Communication Studies

➢ **MSc in Engineering specialising in MATERIALS ENGINEERING (NQF Level 9)**

The Centre for Materials Engineering prepares candidates for the Master of Science in Engineering in Materials Engineering and for the Doctor of Philosophy. The Master of Science in Engineering specialising in Materials Engineering can be either by dissertation only or by coursework (approved by supervisor) and dissertation.

➢ **Doctor of Philosophy (NQF Level 10)**

This is a research (thesis)-based programme in respect of the following focus areas:

- Mechanical Engineering
- Engineering Management
- Sustainable Energy Engineering
- MATERIALS Engineering
- Energy & Development Studies
- Engineering Education

Centre for Materials Engineering[30]

Mission Statement[31]

The UCT Centre for Materials Engineering has the objectives of educating and training students in the broad field of materials science and engineering through focused research activities at BSc(Hons), MSc and PhD levels. At a fundamental level we are concerned with the physical, chemical, electrical and mechanical properties of ceramic, POLYMERIC, metallic and composite MATERIALS and as such we have developed appropriate infrastructure and test facilities to support this activity. Furthermore, our staff complement, including permanent, contract, and visiting personnel, are highly skilled in providing teaching, research and technical support to students, our sponsors, and academic and industry collaborators. Our mission is to use research as a vehicle to develop human capacity through postgraduate enrolment and we promote quality and relevant research through liaison with local and international research partners, industry and government initiatives. The Centre also provides critical infrastructure and input to support the thriving mechanical engineering and mechanical and mechatronic engineering undergraduate programmes that are offered in the Mechanical Engineering Department.

Terms of Reference

- To promote research collaboration across a range of cognate projects and fields in materials science and engineering: (i) with specific attention directed towards materials in manufacturing in order to support the development of a sustainable and competitive manufacturing industry in South Africa, and (ii) with specific attention directed towards the performance of materials in service in order to support component life cycle management in engineering plant, machinery and related systems.
- To define our research agenda: (i) to align with the context in (1) above, (ii) to meet the criteria and expectations of sponsors and potential sponsors, (iii) to match to our expertise and laboratory and equipment capabilities, (iv) to readily translate research output to research publications, and (v) to attract high quality postgraduate students and postdoctoral fellows.
- To provide workspace and facilities/infrastructure to readily support and promote engagement with researchers who share the common objectives described in (1) above.
- To seek and obtain financial support from a broad range of sponsors including government, NRF, industry, the University, and international funding opportunities.
- To publish research output in high quality peer-reviewed international and local journals and conference proceedings.

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[31] Source: www.mateng.uct.ac.za

- To attract students and researchers from diverse backgrounds with particular emphasis on inclusivity and representation of the greater South African and African society.
- To contribute towards teaching at undergraduate and postgraduate levels in order to promote awareness of the importance of materials science and engineering, and to assist in supporting the pipeline for graduates to register for higher degrees in materials engineering

UNDERGRADUATE COURSES OFFERED

Materials Science in Engineering

Admission requirement(s): CEM1008F = Chemistry for Engineers or CEM1000W
Course Outline
An introduction to the science of engineering materials and the relationships between structure and properties.

Testing for strength, hardness, toughness, fatigue and creep. Interpretation of data. Elastic and plastic deformation of solids. Fracture. Visco-elastic and time dependent behaviour. The structure of crystalline, semi-crystalline and amorphous materials. Phase equilibrium diagrams, equilibrium and non-equilibrium structures. Heat treatment. Models of electrical conduction-development of band theory in metals, semi-conductors and insulators. Elements of corrosion science, deterioration and degradation of materials. The principles of reinforcement and design on the properties of composites. The selection of materials. Case studies.

Electrical and Mechanical Materials

Admission requirement(s): PHY1010W
Course Outline
Models of electrical conduction – development of band theory in metals, semi-conductors and insulators. Semi-conductors – importance of impurities. Operation of the p-n junction with reference to materials parameters. Utilisation of the band structure of a semi-conductor to produce novel devices. An introduction to engineering materials and the relations of mechanical, electrical and chemical properties to the structure.

Materials under stress

Admission requirement(s): MEC2042F
Course Outline

- Elasticity and importance of modulus in engineering design
- The influence of bond strength and structure
- Plastic flow in crystals and poly-crystals by dislocation movement.
- Work hardening
- Re-crystallisation
- Strengthening methods in metals
- Effect of temperature, strain rate, stress state
- Failure in metals
- Ductile and brittle fracture
- Critical flaw size and fracture toughness

- Fatigue, creep, stress corrosion and wear processes; dislocation and other micro-mechanisms involved

Manufacturing with Materials

Admission requirement(s): MEC2042F
Course Outline

- Manufacturing materials
- Modelling deformation during processing
- Manufacturing process selection
- Net shape casting processes
- Forming processes, joining processes and machinability of materials
- Surface engineering
- Injection moulding, blow moulding and extrusion of polymeric materials
- Manufacturing and business strategy
- Case studies in product manufacture

Materials Science Laboratory Project

Admission requirement(s): Completion of first three years of study for BSc(Eng) degree
Course outline:
Each student will be given an individual laboratory project on a problem relating to materials. A period of ten weeks is allocated for the project and on completion a treatise must be submitted for examination

Metallic Materials

Admission requirement(s): MEC2042F
Course Outline:
The course is divided into four modules (12 lectures each). The principal themes for the respective modules are as follows:

1. Phase transformations in metals and alloys
2. Metallurgy and properties of ferrous alloys
3. Metallurgy and properties of non-ferrous alloys
4. Introduction to metallic corrosion

Ceramic Materials

Admission requirement(s): MEC2042F
Course Outline:
History of ceramics; traditional ceramics; glasses and glass ceramics; advanced ceramics; chemical bonding in ceramics; physical,, mechanical and chemical properties of ceramics, nucleation and growth phenomena; production and properties of engineering ceramics, refractories, cements and concrete; fracture and reliability of ceramics; ceramic matrix composites; powder technologies; selection and design of ceramic components

Polymeric Materials

Admission requirement(s): MEC2042F
Course Outline:

Polymer nomenclature; morphology; bonding, molecular weight, polymerization, crystallization; polymer types; rheology, manufacturing methods; applications; polymer identification; polymer modification, additives; analytical techniques; biodegradability; selection and design.

Composite Materials

Admission requirement(s): MEC2042F
Course Outline:
History of composites; carbon, glass and aramid fibres; functions of the reinforcement and matrix, polymer-, metal- and ceramic-matrix composites; manufacture of composites; elastic properties of fibre composites; fracture and toughness, the fibre/matrix interface; geometric aspects; laminate theory and the strength of laminates; testing of composites and environmental effects; selection, modification and design of composites.

➢ BSc(Hons) in Materials Science (NQF Level 8)

- One year intensive training in Materials Science
- Open to BSc graduates with three-year degree in Chemistry, Biochemistry, Physics or Geology
- Must have completed BSc in minimum time
- The structured programme of 144 credits of coursework includes a laboratory project

Curriculum outline
Core courses:

- Research project
  Admission requirements: Completion of BSc degree
  Course outline: Students are required to attend a series of lectures and practicals on experimental techniques. Each student will be given an individual laboratory project on a problem relating to materials. A period of twelve weeks is allocated for the project and on completion a treatise must be submitted for examination.

- Manufacture & properties of Composites
  Admission requirements: Course entry requirements: MEC2042F or BSc (Hons) MatSc candidate
  Course outline: This course aims to develop an advanced understanding of the manufacture and properties of composites. Topics include: history of composites; carbon, glass and aramid fibres; functions of the reinforcement and matrix, polymer-, metal- and ceramic-matrix composites; manufacture of composites; thermal properties, elastic properties of fibre composites; fracture and toughness, the fibre/matrix interface; geometric aspects; laminate theory and the strength of laminates; testing of composites and environmental effects; selection, and modification and design of composites.
- Manufacture & properties of Ceramics
  Admission requirements: MEC2042F or BSc (Hons) MatSc candidate
  Course outline: This course aims to develop an advanced understanding of the manufacture and properties of ceramics. Topics include: history of ceramics; traditional ceramics; glasses and glass ceramics; advanced ceramics; chemical bonding in ceramics; physical, mechanical and chemical properties of ceramics, nucleation and growth phenomena; production and properties of engineering ceramics, refractories; fracture and reliability of ceramics; powder technologies; and selection and design of ceramic components.

- Manufacture & properties of Metallics
  Admission requirements: MEC2042F or BSc(Hons) MatSc candidate
  Course outline: This course aims to develop an advanced understanding of the properties and manufacture of metallic materials. The course covers four main topics, namely, the solidification process; the metallurgy of ferrous, non-ferrous and light metal alloys; the relationship between manufacturing processes, mechanical properties and microstructures of metallic materials; and an introduction to metallic corrosion. The course also includes a week-long intensive module on wrought aluminium processing.
- Manufacture & properties of Polymers
  Admission requirements: MEC2042F or BSc(Hons) MatSc candidate
  Course outline: This course aims to develop an advanced understanding of the manufacture and properties of polymers. Topics include: polymer nomenclature; morphology; bonding; molecular weight, polymerization, crystallisation; polymer types; rheology; manufacturing methods; applications; polymer identification; polymer modification, additives; analytical techniques; biodegradability; and selection and design
- Experimental Techniques in Materials Science

Elective courses:

- Mineral and Metallurgical Processing
- Materials under Stress
- Production Processes
- Manufacturing with Materials

Admission requirements: MEC2042F or co-registration of BSc(Hons) MatSc
Course outline: This course aims to develop an advanced understanding of manufacturing materials. Topics include: modelling deformation during processing, manufacturing process selection, net shape casting processes, forming processes, joining processes and machinability of materials, surface engineering, injection moulding, blow moulding and extrusion of polymeric materials, manufacturing and business strategy, case studies in product manufacture.

- Materials under stress
- Phase transformations
  Admission requirements: MEC3060F
  Course outline: This course aims to give an understanding of the thermodynamics and kinetics of phase transitions. It covers the following topics: the application of thermodynamics in kinematics in materials science and engineering; thermodynamic states of variables; the first law of thermodynamics (energy conservation law); phase transitions (liquid/solid and solid state matter); single component and binary systems; equilibrium phase diagrams; and diffusion in liquid and solid state matter.
- Professional communications

POSTGRADUATE STUDIES

At any time there are between fifteen and twenty Masters and Docatoral students in Materials Engineering

5. University of Pretoria

Department of Chemical Engineering

➢ **BEng Chemical Engineering**

Programme information

All fields of study of the BEng degree have been accredited by the Engineering Council of South Africa (ECSA), and comply with the academic requirements for registration as a professional engineer. The programmes are designed in accordance with the outcomes-based model as required by the South African Qualifications Authority (SAQA). The learning outcomes and contents of the programmes have been compiled in accordance with the latest accreditation standards (PE-60 and PE-61) of ECSA, which also comply with the SAQA requirements, and which are summarised as follows:

Learning outcomes of the BEng degree:

A graduate in engineering should be able to apply the following skills on an advanced level:

1) *Problem solving* – demonstrate competence to identify, assess, formulate and solve convergent and divergent engineering problems creatively and innovatively.
2) *Application of scientific and engineering knowledge* – demonstrate competence apply specialist and fundamental knowledge, with specific reference to mathematics, basic sciences and engineering sciences; from first principles to engineering problems.
3) *Engineering design and synthesis* – demonstrate competence to perform creative, procedural and non-procedural design and synthesis of components, systems, engineering works, products or processes.
4) *Investigation, experimentation and data analysis* – demonstrate competence to design and conduct investigations and experiments.
5) *Engineering methods, skills and tools* – demonstrate competence to use appropriate engineering methods, skills and tools, including those based on information technology.
6) *Professional and general communication* – demonstrate competence to communicate effectively, both orally and in writing, with engineering audiences and the community at large.
7) Awareness and knowledge of the *impact of engineering activity* on *social, industrial* and the *physical environments*.
8) *Work effectively* as an *individual*, in *teams* and in *multidisciplinary environments*.
9) *Life-long learning* – awareness of the need for lifelong learning and ability to engage in independent learning through well-developed learning skills.
10) *Engineering professionalism* – awareness and knowledge of principles of professional ethics and practice and exercise judgment and take responsibility within limits of competence.
11) *Engineering management* – knowledge and understanding of engineering management principles and *economic decision-making*.

Admission requirements

- The following persons will be considered for admission: a candidate who is in possession of a certificate that is deemed by the University to be equivalent to the required Grade 12 certificate with university endorsement; a candidate who is a graduate from another tertiary institution or has been granted the status of a graduate of such an institution; and a candidate who is a graduate of another faculty at the University of Pretoria.
- Life Orientation is excluded when calculating the APS.
- Grade 11 results are used in the conditional admission of prospective students.
- A valid qualification with admission to degree studies is required.
- Minimum subject and achievement requirements, as set out below, are required.
- Conditional admission to the four-year programmes in the School of Engineering is only guaranteed if a prospective student complies with ALL the requirements below.

  Note: Candidates who do not comply with the minimum requirements, set out above, but who have obtained a minimum APS of 30, an achievement level of 5 for English, 6 for Mathematics and 5 for Physical Science, will be considered for conditional admission to either the four-year programme or the ENGAGE programme based on the results of the NBT.

  - Admission to ENGAGE in the School of Engineering will be determined by the results of the NBT, NSC results, an achievement level of 5 in Mathematics and 4 in Physical Science, as well as an achievement level of 4 in English, together with an APS of 25.
  - Students may apply directly to be considered for the ENGAGE programme.

Core modules

YEAR 1

- General chemistry
- Chemical engineering
- Electricity and electronics
- Physics
- Humanities and social sciences
- Graphical communication
- Mechanics
- Calculus
- Mathematics
- Workshop practice

YEAR 2

- Engineering statistics
- Chemistry
- Chemistry
- Chemical engineering materials
- Chemical engineering
- Thermodynamics
- Electrical engineering
- Community-based project

- Programming and information technology
- Strength of materials
- Mathematics
- Differential equations
- Calculus
- Numerical methods

YEAR 3

- Engineering management
- Biochemical engineering
- Chemical engineering design
- Chemical engineering
- Professional and technical communication
- Kinetics
- Laboratory
- Mass transfer
- Transfer processes
- Process dynamics
- Practical training
- Engineering activity and group work

YEAR 4

- Particle technology
- Process control
- Design project
- Chemical engineering practice
- Process synthesis
- Process analysis
- Practical training
- Reactor design
- Research project
- Research project
- Specialisation

➢ **BEng Metallurgical Engineering**

Programme information

All fields of study of the BEng degree have been accredited by the Engineering Council of South Africa (ECSA), and comply with the academic requirements for registration as a professional engineer. The programmes are designed in accordance with the outcomes-based model as required by the South African Qualifications Authority (SAQA). The learning outcomes and contents of the programmes have been compiled in accordance with the latest accreditation standards (PE-60 and PE-61) of ECSA, which also comply with the SAQA requirements, and which are summarised as follows:

Learning outcomes

As above for BEng in Chemical Engineering

Minimum requirements

As above for BEng in Chemical Engineering

Curriculum Outline

Year 1

Core modules

- General chemistry
- Electricity and electronics
- Physics
- Humanities and social sciences
- Graphical communication
- Materials science
- Mechanics
- Calculus
- Mathematics
- Workshop practice

Year 2

- *Core modules*
- Engineering statistics
- Electrical engineering
- Mineralogy
- Community-based project
- Programming and information technology
- Dynamics
- Professional and technical communication
- Materials science
- Process thermodynamics
- Mathematics
- Differential equations
- Calculus
- Numerical methods

Year 3

- Engineering management
- Engineering activity and group work
- Thermoflow
- Electrochemistry
- Excursions
- Hydrometallurgy
- Materials science
- Mechanical metallurgy
- Minerals processing

- Pyrometallurgy
- Industrial training
- Refractory materials

Year 4

- Engineering professionalism
- Hydrometallurgy
- Minerals processing
- Process design
- Process metallurgy and control
- Metals processing
- Industrial training
- Literature survey

POST GRADUATE STUDIES

Department Of Chemical Engineering

SARChI Chair in Carbon Technology and Materials

BEng (Hons) Chemical Engineering / BSc (Hons) (Applied Science)

MEng (Chemical Engineering) / MSc (Applied Science)

➢ **BEngHons in Chemical Engineering**

- Bioprocessing
- Fluoro-materials science research and technology
- Chemical engineering
- Environmental nanomaterials
- Carbon materials science research and technology 0
- Product design
- Polymer processing
- Polymer materials science and research
- Bio-reaction engineering
- Research orientation
- Separation technology
- Process control system research and development
- Additive technology
- Biological water treatment

➢ **BScHons in Applied Science (Chemical Technology)**

The BScHons (Applied Science) degree is conferred by the following academic departments:

- Chemical Engineering
- Civil Engineering
- Industrial and Systems Engineering
- Materials Science and Metallurgical Engineering

- Mechanical and Aeronautical Engineering
- Mining Engineering

Admission requirements

An appropriate bachelor's degree, a BTech degree or equivalent qualification is required for admission

Core modules

- Bioprocessing
- Fluoro-materials science research and technology
- Process integration
- Chemical Engineering
- Carbon materials science research and technology
- Particle technology
- Process control
- Product design
- Polymer processing
- Polymer materials science and research
- Reactor design
- Separation technology
- Specialisation
- Additive technology

Module Descriptions

<u>Product Design (1st Semester)</u>

The methodology to develop chemical products involves assessing needs, generating ideas, sorting and screening ideas, development of good ideas, and assessment of manufacturing methods. Engineering principles must be used to estimate whether the performance of the product will meet requirements, and involves the application of e.g. thermodynamics of mixing, phase equilibrium, solutions, surface chemistry, diffusion, and transport properties. Students will choose a need for suitable chemical product, and implement the product design process and techniques to arrive at a unique product that meets the need. Students will present their projects both orally and as a written report.

<u>Polymer Materials Science (1st Semester)</u>

Introduction to polymers as materials. Concepts, nomenclature and synthesis of polymers. Characterization of polymers. Phase structure and morphology of bulk polymers: the amorphous state, the crystalline state, multicomponent polymer systems. Properties of bulk polymers: elastic deformation, viscoelasticity, elastomers, yield and crazing, facture and toughening, polymer composites, electrical properties.

<u>Polymer Processing (1st Semester)</u>

Unit processes in polymer processing. Analysis of complex processes: Description in terms of elementary processing steps. Transport phenomena: Transport equations, rheology and mixing processes. Elementary process steps: Particle technology, melting, pumping, pressure elevation, mixing, modelling of processes. Forming: Extrusion, calendering, injection moulding, and film blowing. Reactive processing: Thermo-set materials, reaction kinetics.

Additive Technology (1st Semester)

Property modification through reactive processing and additive compounding. Colorants and optical modifiers (pigments, dyes, absorbers and opacifiers), fillers and reinforcements; Stabilisers (anti-oxidants, light stabilisers, flame retardants); Surfactants (antistatic, antifog and antiblock); Functional additives (gas absorbers, biocides, foaming agents, barrier additives and cross-linkers); Viscosity modifiers. Optimisation of formulations using statistical methods: Taguchi experimental designs and triangular formulation designs.

Fluoro-Materials Science (1st Semester)

Historical review of fluorine chemistry. Health and safety aspects of fluorochemicals: the interaction of hydrogen fluoride, fluorine, and fluorides with biological tissue; safe practice; emergencies; exposure limits. Production of hydrogen fluoride. Electrolytic production of fluorine gas: basics of fluorine cell technology; contaminants; purification. Inorganic fluorides: their synthesis, properties, and reactivities; industrial uses; dry fluorination. The use of hydrofluoric acid in hydrometallurgy. Introduction to organic fluorine chemistry: properties of fluoro-organics; preparation; analysis; fluorous phase; direct fluorination; electrochemical fluorination. Organic fluorides as etchants in plasma and semiconductor technologies. The role of fluorine chemistry in Li-ion batteries: electrolytes; solvents; intercalated graphite; CFx materials. Fluoro-polymers: their properties; applications; markets; preparation of important industrial fluoro-monomers; characterisation techniques; polymerisation and manipulation of physical properties; processing; thermal behaviour. Particularly strong emphasis is placed on the thermodynamics and kinetics of fluorochemical processes throughout.

Carbon Materials Science & Technology (1st Semester)

Materials science of carbon and graphite materials: Pitch, mesophase, cokes, synthetic carbons, bulk carbon and graphite, carbon fibres and matrices, sintered carbon, carbon/carbon composites and nuclear graphite. Carbon nanotechnology. Characterization of carbon materials: crystallography (powder X-ray diffraction), thermogravimetric and differential scanning calorimetry, thermo-mechanical analysis, infrared and Raman spectroscopy. Processing of carbon materials.

Chemical Engineering (1st Semester and/or 2nd semester)

A self-study module, the content of which is discussed with the relevant lecturer. In addition, the course will include a basic introduction to analytical techniques relevant to materials research. The topics covered are:

- Imaging: SEM to optical microscopy
- Spectroscopy: FTIR to Raman & UV-Vis-NIR
- Chromatography: ICP-MS to liquid and gas chromatography
- X-ray analysis: XRF, XRF to X-ray tomography
- Thermal analysis: TGA, DSC, DTA, DMA & TMA
- Bulk properties: particle size, porosity, surface area, rheology, conductivity, etc.

MEng (Chemical Engineering)

MSc (Applied Science)

6. Wits University

School of Chemical and Metallurgical Engineering

UNDERGRADUATE STUDIES [32]

- **BSc (Eng) in Metallurgy and Materials Engineering**

A ***four-year*** degree programme at ***NQF Level 8***.

Fees: R51,830 per annum

Curriculum

This engineering course covers engineering principles required to concentrate, extract and refine metals, materials and carbon materials as well as developing new alloys, materials, ceramics and composites.

Students of materials engineering take courses on engineering sciences related to materials (micro structure, crystal structures, the structure and properties of materials) and the processing and behaviour of materials (materials processing, heat treatment, corrosion, wear, welding and forming processes, failure analysis, and powder metallurgy).

Core subjects in materials engineering focus on the structure and behaviour of materials (failure analysis, crystal structures, corrosion and wear) and their formation into usable forms (heat treatment, welding and forming processes, and powder metallurgy).

As in the chemical engineering curriculum, the curriculum also focuses on the issues of environmental engineering, management and professional ethics. There is a strong emphasis on design and project work and the programme culminates with an extensive laboratory project and a large design project. Altogether, the degree programme provides a sound foundation for future postgraduate study as well as a career in technical management.

The *first two years* of study are mostly common to both disciplines, while the last two years offer opportunities for specialisation in either Chemical Engineering or Metallurgical Engineering.

In addition to the necessary courses in the basic sciences, there are first and second year courses which provide students with an introduction to the analysis of Chemical Engineering as well as Metallurgical and Materials principles and practices.

Towards the *end of the second year* the Chemical Engineering students *cover more specialised process engineering topics* while the Metallurgical Engineering students study various aspects of the extraction, refining and application of several key metals.

The curriculum is designed to provide students with a solid base for their diverse careers by *emphasising* sound *problem-solving abilities* in conjunction with a thorough understanding of the *principles of engineering*.

[32] The University's undergraduate engineering degrees are recognised by the Engineering Council of South Africa and have received the approval of professional accrediting bodies in the USA, Canada, Australia, New Zealand, the UK, Ireland and Hong Kong.
www.wits.ac.za/course-finder/undergraduate/ebe/chemical-engineering/

During the vacation at the end of third year, students are required to obtain ***practical experience*** by working with an engineering company that deals with chemical engineering and/or metallurgical engineering practices. The fourth year curriculum allows a student to choose a number of optional courses, depending on aptitudes and interests

1st Year:

- Introduction to Process and Materials Engineering
- Chemistry I
- Physics *Qualifying course for BSc(CS), BSc Eng (Chem) and BSc Eng (Met & Mat)*
- Mathematics I
- Critical Thinking
- A Social History of Technology

2nd Year

- Computing for Process Engineers
- Process Engineering Fundamentals
- Energy Balances and Applications
- Chemistry II (Metallurgy)
- Electrical Engineering
- Economic Concept *Qualifying course for BSc(URP)*
- Mathematics II

3rd Year

- Transport Phenomena (2 terms)
- Chemical Engineering Thermodynamics (2 terms)
- Chemical Engineering Laboratory (2 terms)
- Mass Transfer (1 term)
- Numerical Methods (1 term)
- Chemical Reaction Engineering (2 terms)
- Chemical Design Principles (2 terms)
- Environmental Process Engineering (1 term)
- *Vacation Work*

4th Year

- Hydrometallurgy
- Management for Process Engineers
- Solid Fluid Systems
- Chemical Engineering Design
- Process Control
- Advanced Chemical Engineering B
- Advanced Chemical Engineering C
- Advanced Chemical Engineering D
- Chemical Engineering
- Biochemical Engineering

POSTGRADUATE STUDIES

The School of Chemical and Metallurgical Engineering has three very active postgraduate research programmes.

There are three broad postgraduate programmes on offer.

- **Postgraduate Diploma in Engineering (EXA00)**

This is a postgraduate programme obtained through coursework; it is available in various fields of Metallurgy such as Pyrometallurgy, Welding, Materials Science plus Engineering. It is also available in the Fields of Chemical Engineering, viz Oil & Gas Engineering and Chemical Engineering.

- **MEng in Metallurgy and Materials Engineering**

This is a year-long block course only offered in certain Metallurgical Engineering (Welding Engineering only).

- **MSc (Eng) in Metallurgy and Materials Engineering**

There are two options for the MSc (Eng):

- MSc 50:50 half taught courses (1 year) and a research dissertation with limited scope (minimum duration1 year)
- A full research programme with (minimum 2 years)

- **Doctor of Philosophy (PhD) (EDA02)**

The PhD is obtained by research work that makes an original contribution to the advancement of knowledge in the field of study.