ABSTRACT

Industrial engineering is the application of scientific principles in the design, development, improvement, implementation and maintenance of integrated systems of men, materials, machines and money for process optimization. It extracts expert knowledge and skills from physical sciences and mathematics infused with the principles of engineering analysis methods to maximize system utilization. South Africa remains constrained by its low growth potential. Slow private investment growth and weak integration into global value chains prevent the country from reaping the new economic opportunities emerging around the globe, and from catching up with living standards in peer economies. South Africa needs to build on its comparative advantages, that of an industrially skilled economy, to develop new domestic and international markets through higher productivity and innovation. Industrial engineering as a practice is central in improving productivity and cultivating innovation. As a result, the University of South Africa is in an advantageous position due to its reach, reputation and flexibility to disseminate the qualification in Industrial Engineering that will positively impact on the South African economy. However, the enrolment figures in Industrial Engineering are disappointing compared to other engineering disciplines. The research aimed to determine awareness and understanding of Industrial Engineering as a field among students in order to understand the factors that might be responsible for the low enrolment, throughput and graduation rates using quantitative analysis. In addition, the curriculum of the current programme was evaluated to determine its relevance and its adaption to ever-changing material conditions.

Keywords: Industrial engineering, enrolment rates, graduation rates.
1 INTRODUCTION AND BACKGROUND

Perception has a hidden importance in society in general, it is the motive force behind certain decisions including which university students chose at and which course students enrol for, and which career students follow[2]. The Department of Mechanical and Industrial Engineering (DMIE) in the School of Engineering at the University of South Africa (UNISA) take cognisance of such perceptions and postulates that the low enrolment rates could be as a result of the lack of a proper understanding of what an industrial engineer is, amongst academics, industry and the students. This perception was brought to the fore by the different titles with which industrial engineers are referred to. These include quality engineer, manufacturing engineer, project manager, quality control supervisor and systems analyst, amongst many others. Low enrolment rates could also be linked to the perception that could be held by students, that UNISA could not be ideal institution to offer engineering programmes due to its character as a distance learning institution noting further that the discipline requires practical tuition as well. UNISA has traditionally accommodated students who are already working as a result able to apply theory learned at their respective workplaces.

UNISA has over the recent past experienced enrolment of students straight from matric due to affordable tuition UNISA offers, however while other disciplines have experienced a high enrolment rates for instance, mechanical engineering; the opposite (dwindling) enrolment rates were applicable to industrial engineering.

It is with these concerns and speculations that the department approached the Directorate: Institutional Research to assist with conducting a survey aimed at investigating the reasons for the low graduation rates and poor enrolment rates observed in industrial engineering. It is envisaged that the results of the study will clear perceptions of what the discipline is all about and as a result attract quality students which requires the university to be at the forefront of advocacy for the discipline. With quality student enrolment matched by quality tuition the throughput will improve and so will the graduation rates.

The University of South Africa (UNISA) prides itself as an Open Distance and e-Learning (ODeL) institution with a range of cost effective and quality programmes designed to address global needs. However, despite this, the university faces a number of challenges, which if not considered and acted upon, will impact on its effectiveness and sustainability [3]. Amongst these is the need to “rationalise, reengineer and reposition programmes which are no longer financially viable”. In other words, UNISA aims to focus its energies and resources on the improvement of quality, service delivery and improved throughputs with a special emphasis on programmes with low-enrolment rates [3][4]. The current difficulties in enrolment rates with regard to industrial engineering requires the university to re-evaluate its feasibility and implement innovative solutions to make the offering sustainable now and in the future.

2 METHODOLOGY

Principally the quantitative approach was adopted as it enables the researcher to focus in a particular area and gather information through various means. In this case study, data was collected through the review of existing literature and triangulated with questionnaires and telephonic discussions. Data was collected by means of a short online survey which had been developed and pre-tested by the Directorate: Institutional Research. The survey comprised a combination of mainly closed ended and some open-ended questions covering students’ employment, study choice and knowledge of Industrial Engineering as a field [5]. The survey was conducted in January 2016 and delivered to industrial engineering students’ myLife email addresses through qualtrics lab software.
This survey was conducted after the research team had sought and obtained the necessary ethical clearance from UNISA. Students’ myLife email addresses were provided by the Department: Information and Communication Technology (ICT). Students whose email addresses were requested from ICT were those who had registered for the National Diploma: Industrial Engineering and the Bachelor of Technology: Industrial Engineering during the 2012-2016 academic years.

3 LITERATURE REVIEW

Industrial engineering as a discipline that deals with the design of human effort in all occupations, e.g. agricultural, manufacturing and service, with the aim of optimizing the productivity of work-systems and the occupational comfort, health, safety and income of persons involved [6]. Industrial engineering focuses on business efficiency - or more precisely, on how to design, organise, implement, and operate the basic factors of production and manufacturing (materials, equipment, people, information, and energy) in the most efficient manner possible so as to optimize industrial manufacturing operations, although the skills learned are applicable to other non-manufacturing settings [7]. This makes industrial engineering a multi-disciplinary field of study that equips graduates with the necessary technical background, as well as the economic and people skills vital to making economically justifiable decisions in a business environment [8].

The demand for industrial engineers in South Africa has increased significantly as was illustrated by the listing of Industrial Engineering as a national scarce and critical skill in 2006, and the consequent release of 5 000 quota work permits by the Department of Home Affairs for appropriately qualified foreign nationals. In the national engineering database (August 2007), the total number of professionally registered engineers, technologists and technicians was 5 000, 1 900 and 6 700, respectively. Annually, 2 000 learners register for National Diplomas in engineering but “as a result of poor throughput and their inability to get experiential training, only 500 to 600 graduate [9;10;11].

In March 2005, the total number of registered professional engineers in Industrial Engineering was only 225, representing 1% of the total number of professional engineers in South Africa. The Business Times in March 2007 indicated that “…the shortage of skills - such as industrial engineers, supply chain managers, warehousing and distribution experts, and network analysts - is a crisis that will erode South Africa’s competitiveness” [8].

To meet the skills demands in South Africa, an extra 1 000 engineers are required to graduate every year (reference). Though these statistics are not very recent, the general picture has not changed and makes industrial engineers one of the most sought-after human resources due to their skills cutting across various industries [12;8;6].

However, despite this, UNISA has been experiencing low enrolment and graduation rates for this particular programme at both the National Diploma and the Bachelor of Technology levels. The objective of this research is to present key interventions to address this conundrum.

4 FINDINGS

Please note that this is a large study and only certain results are presented.

4.1 Response rate

Table 1 below provides the overall response rate to the survey and the response rate of students who consented to participate.
The survey was sent to 1,244 students who were identified as enrolled for qualifications in Industrial Engineering as at 21 January 2016 by the Department: Information and Communication Technology. Of these, 146 (11.7%) opened the survey and 134 (10.8%) agreed to participate. It is important to note that this is a poor response rate and measures were taken to improve in another survey. Thus it was decided to present the results as is.

4.2 Demographics

Table 2 provides the race of the population of students enrolled for Industrial Engineering qualifications as well as the respondents’ race and the response rate to the survey. The response rate is given as a proportion of the overall population total.

<table>
<thead>
<tr>
<th>Race</th>
<th>Population N</th>
<th>Population %</th>
<th>Respondents N</th>
<th>Respondents %</th>
<th>Response rate</th>
</tr>
</thead>
<tbody>
<tr>
<td>White/Chinese</td>
<td>242</td>
<td>19.5%</td>
<td>25</td>
<td>19.7%</td>
<td>2.0%</td>
</tr>
<tr>
<td>Coloured</td>
<td>43</td>
<td>3.5%</td>
<td>4</td>
<td>3.1%</td>
<td>0.3%</td>
</tr>
<tr>
<td>African</td>
<td>897</td>
<td>72.1%</td>
<td>89</td>
<td>70.1%</td>
<td>7.2%</td>
</tr>
<tr>
<td>Indian</td>
<td>60</td>
<td>4.8%</td>
<td>9</td>
<td>7.1%</td>
<td>0.7%</td>
</tr>
<tr>
<td>Other/Unknown</td>
<td>2</td>
<td>0.2%</td>
<td></td>
<td>0%</td>
<td></td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td>1,244</td>
<td>100%</td>
<td>127</td>
<td>100%</td>
<td>10.2%</td>
</tr>
</tbody>
</table>

From Table 2, it is evident that there were 1,244 students enrolled for qualifications in Industrial Engineering at UNISA as at 27 January 2016 (the date the data was extracted by UNISA, ICT). The majority of these students were African - 897 (72.1%), followed by Whites/Chinese at 242 (19.5%), then Indians at 60 (4.8%) and Coloureds at 43 (3.5%) of the population.

A look at the racial distribution of the respondents’ points to representative sample being achieved for all race groups, with the exception of Indians whereby the proportion of respondents (7.1%) is higher than that of the population (4.8%). Lastly, in terms of the response rate, the racial distribution mirrors that of the population in that Africans constituted the majority of the respondents, followed by Whites/Chinese, then Indians and Coloureds.

4.3 Gender

With regard to the gender distribution of enrolled Industrial Engineering students, over 70.0% were males relative to approximately 27.0% who were females.
### Table 3: Respondents by gender

<table>
<thead>
<tr>
<th></th>
<th>Population</th>
<th>Respondents</th>
<th>Response rate</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>N</td>
<td>%</td>
<td>N</td>
</tr>
<tr>
<td>Female</td>
<td>332</td>
<td>26.7%</td>
<td>40</td>
</tr>
<tr>
<td>Male</td>
<td>912</td>
<td>73.3%</td>
<td>87</td>
</tr>
<tr>
<td>Total</td>
<td>1 244</td>
<td>100%</td>
<td>127</td>
</tr>
</tbody>
</table>

Considering the sample relative to the population, a slight over-representation of females (31.5% vs. 26.7%) and a slight under-representation of males (68.5% vs. 73.3%) are observed. However, despite this over-representation, the distribution of the responses was similar to the population distribution in that males constituted the majority of the respondents.

#### 4.4 Employment status

### Table 4: Employment status

<table>
<thead>
<tr>
<th></th>
<th>N</th>
<th>%</th>
<th>Valid %</th>
</tr>
</thead>
<tbody>
<tr>
<td>Employed</td>
<td>94</td>
<td>70.1%</td>
<td>74.0%</td>
</tr>
<tr>
<td>Unemployed</td>
<td>31</td>
<td>23.1%</td>
<td>24.4%</td>
</tr>
<tr>
<td>Self employed</td>
<td>2</td>
<td>1.5%</td>
<td>1.6%</td>
</tr>
<tr>
<td>Total</td>
<td>127</td>
<td>94.8%</td>
<td>100.0%</td>
</tr>
</tbody>
</table>

As presented in Table 4, most of the respondents (74.0%) indicated that they were employed relative to 24.4% who were unemployed and 1.6% who were self-employed. This confirms that UNISA caters mostly for employed students that have to balance studies and work.

#### 4.5 Employment sector

With regard to the sectors within were they are employed, most students selected the manufacturing sector (47.9%) followed by those who selected “other”.

[4134]-5
Figure 1 highlights the following salient points:

- Transport, Storage and Communication accounted for 7.3%. Military, Government, Electricity and Gas as well as Aerospace and Airplanes were at 5.2% respectively.
- The sectors with the lowest proportions of students were Agriculture, Forestry and Fishing as well as the Banking and Finance sector, with 1% each.

Lastly, with regard to the respondents who had indicated “other”, the following were the specified sectors: healthcare, import-export, logistics and supply chain management, mining, nuclear industry, petrochemical, sales and telecommunications.

### 4.6 Current position

**Table 5: Current position of students**

<table>
<thead>
<tr>
<th>Vocation</th>
<th>Number</th>
</tr>
</thead>
<tbody>
<tr>
<td>Industrial Engineering Technician</td>
<td>19</td>
</tr>
<tr>
<td>Project Manager</td>
<td>9</td>
</tr>
<tr>
<td>Operations Manager/Engineer</td>
<td>7</td>
</tr>
<tr>
<td>Production Planner</td>
<td>7</td>
</tr>
<tr>
<td>Logistics Engineer/Analyst/Manager</td>
<td>6</td>
</tr>
<tr>
<td>Customer Service Excellence</td>
<td>5</td>
</tr>
<tr>
<td>Supply Chain Management</td>
<td>5</td>
</tr>
<tr>
<td>Team Leader</td>
<td>5</td>
</tr>
<tr>
<td>Maintenance Engineer</td>
<td>4</td>
</tr>
<tr>
<td>Quality Engineer/ Manager</td>
<td>4</td>
</tr>
</tbody>
</table>

n=96
Table 5 provides the current positions of the 96 students who had indicated that they were employed. Evidently, when analysing at the current positions that the respondents occupy one observes that there is great variety, and the following is observed:

- Most of the students (19) were employed as Industrial Engineering Technicians which is not surprising, followed by Project Managers at 9.
- Production planners and Operations Engineers are tied in third place at 7 respectively.
- In the fourth place are Logistics and Management Engineers with 6 students.
- Supply Chain and Customer Service Excellence and Team Leader are in the fifth place with 5 respondents.
- Quality and Maintenance Engineers are each sitting in sixth place with 4 respondents.
- Information Systems Specialist, Continuous Process Improvement Specialist, Technical Sales Engineer and General Managers were in seventh place with 3 respondents each.
- The second lowest numbers are for Systems Engineers, Safety Officers, Process Analysts, Manufacturing and Production Engineers with 2 respondents each.
- The lowest numbers are observed for Business Analysts, Entrepreneurs as well as Sales and Operational Planner positions with only 1 student each.

<table>
<thead>
<tr>
<th>Position</th>
<th>Count</th>
</tr>
</thead>
<tbody>
<tr>
<td>Continuous Process Improvement Specialist</td>
<td>3</td>
</tr>
<tr>
<td>Information Systems Specialist</td>
<td>3</td>
</tr>
<tr>
<td>General Manager</td>
<td>3</td>
</tr>
<tr>
<td>Technical Sales Manager</td>
<td>3</td>
</tr>
<tr>
<td>Manufacturing Engineer</td>
<td>2</td>
</tr>
<tr>
<td>Process Analyst/Engineer</td>
<td>2</td>
</tr>
<tr>
<td>Production Supervisor/Manager</td>
<td>2</td>
</tr>
<tr>
<td>Safety Officer/Manager</td>
<td>2</td>
</tr>
<tr>
<td>Systems Engineer/Consultant</td>
<td>2</td>
</tr>
<tr>
<td>Business Process Analyst</td>
<td>1</td>
</tr>
<tr>
<td>Entrepreneur</td>
<td>1</td>
</tr>
<tr>
<td>Sales and Operations Planner</td>
<td>1</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>96</strong></td>
</tr>
</tbody>
</table>
4.7 Duration of employment

With regard to how long the respondents have been employed,

- Most of the respondents (43) (44.8%) of the 96 respondents indicated that they have been working for a period of 5 to 10 years.
- Only 23 (24%) have been working for a period more than 10 years, followed by 18 (18.8%) that have worked for two to four years.
- Less than ten, i.e. 8 (8.3%) had been working for one to two years and 4 (4.2%) had only been employed for one year.

4.8 Study choice

When asked about whether Industrial Engineering was their first choice, 80 respondents (63.0%) indicated that it was a first choice relative to 47 respondents (37.0%) who indicated that it was not their first choice.

Respondents who had stated that Industrial Engineering was not their first choice of study (47) were then asked why they had not registered for their first choice.
Figure 4: The reason for not registering for first choice

The following reasons were provided by the respondents:

- Most of the respondents - 29 (61.7%) indicated that they had registered for their first choice but later transferred to Industrial Engineering.
- This was followed by 14 (29.8%) who indicated “other” and lastly four (8.5%) who indicated that they did not qualify for their first choice hence they registered for Industrial Engineering.

Those who had stated “other” provided some of the following reasons (unedited quotes):

- “Company wouldn’t allow me to register for mechanical diploma”
  “Engineering is more interesting and pilot can be a hobby”
- “I have a B. Com Honors. Thought it good to get credits for previous engineering & Commerce studies.”
- “I became interested in the diversity of holding and practicing Industrial Engineering instead continuing with my initial choice.”
- “Qualified as an Electrical Engineer. When I started working I become more interested in Industrial Engineering”
- “too late for electrical engineering”
- “Change of career path”

4.9 Study influence

All 127 respondents with valid responses were then asked to indicate what had influenced their decision to study Industrial Engineering. As this was a multiple response question, 187 responses were received from the 127 respondents, hence the sum of the proportions exceed 100%.
The following reasons were provided by the respondents:

- The job prospects that a qualification in Industrial Engineering offered was the most popular response (69.3%) followed by “other” at 22.0%.
- Career guidance at school was the third highest influence at 16.5% followed by the prospects of a better salary at 14.2% and those who were of the opinion that Industrial Engineering was easier than other Engineering disciplines (11.0%).
- Influence by peers and influence by family were the least popular responses at 6.3% and 4.7% respectively.

4.10 Knowledge of Industrial Engineering

In assessing students’ knowledge of what Industrial Engineers do, students were asked to rate their agreement with various statements. A total of 11 statements were presented, 7 of which correctly described what Industrial Engineers do with 4 being incorrect. Statements were deliberately mixed in order to test their level of knowledge and understanding of the discipline of Industrial Engineering.

On evaluation of the information the following was revealed:

- The majority of students are aware of the types of work Industrial Engineers do.
- Only between 0.9%-13.4% rated the correct statements “False”.
- One of the four incorrect statements was correctly rated “False” by 72.4% of the respondents.
- Therefore 8 of the 11 statements were correctly identified.
- There seems to be a notable range in the responses among the students with regard to the incorrect statements, revealing their confusion.
- Between 27.6% and 76.7% rated the incorrect statements as being true.

4.11 Type of work Industrial Engineers do

Students’ knowledge of the techniques used by Industrial Engineers was better than their knowledge of the type of work that Industrial Engineers do as evidenced by the high
proportions who rated the statements true (90.4%-99.1%). When ranking the techniques rated as true to Industrial Engineering, the results were as follows:

- Project management had the highest rating at 99.1%.
- Tied in second place was Organisational Analysis, Flow Diagramming, Strategic Planning, Statistical Analysis and Information Data Flow at 98.3% respectively.
- The technique with the lowest proportion was Modelling at 90.4%.

5 CURRICULUM REVIEW

The qualification is responsive to the economy and society as it addresses some of the training needs indicated in the Higher Education & Training Framework for the National Skills Development Strategy (NSDSIII). Also, the qualification adheres to HEQSF in terms of appropriateness, coherence and consistency, articulation pathways and facilitates equity of access in higher education as gleaned from the document which is not publicly viewable at present [13;9;14].

Skilled engineering technicians are required to meet the developmental needs of the country in all service, manufacturing and industrial production fields. Responsiveness to local context takes into account skills development, diversity, equity, redress and increasing access and the extended curriculum. The programme is responsive to international regulatory requirements through the Engineering Council of South Africa (ECSA) and recognized by the Dublin Accord. The Dublin Accord is an agreement for the international recognition of Engineering Technician qualifications.

This qualification is primarily vocational, or industry-oriented, characterised by the knowledge emphasis, general principles and application through technology transfer. The qualification provides students with a sound knowledge base in industrial engineering and the ability to apply their knowledge and skills to a career in industrial engineering, while equipping them to undertake more specialised and intensive learning. Holders of this qualification are usually prepared to enter a specific niche in the labour market. The programme is articulated to the National Qualification Framework (NQF) level 10 so that it provides lifelong professional development as students are required to engage with complexity and changing technology in the engineering environment in UNISA’s newly constructed laboratories. The qualification is economically responsive to the economy and society as it addresses some of the training needs indicated in the Higher Education & Training Framework for the National Skills Development Strategy (NSDSIII). Skilled engineering technicians are required to meet the developmental needs of the country in all service, manufacturing and industrial production fields [15; 16;17].

In terms of cultural responsiveness, ELO 6 (engineering learning outcome) in the Form 1 document which concerns the ability of engineers to communicate effectively, both orally and in writing within an engineering context. They should also demonstrate knowledge and understanding of the impact of engineering activity on the society, economy, workplace and physical environment, and address issues by defined procedures. The 27 credit module is included in year one in the section of complementary studies specifically dealing with aspects related to the ability to communicate effectively at all levels both inside and outside the organization and be sensitive to cultural issues when dealing with society which would be done in the laboratory through role plays and through team based learning which involves simulation. The outcome is assessed through both summative and formative assessments.
The diploma in engineering technology is responsive to the knowledge discipline through engagement of students in “systematised forms of enquiry” that considers Luckett’s model that is broken into four spheres and alludes to discipline specific knowledge to knowledge application. Academic staff possesses the disciplinary qualification and expertise for the programme and many are engaged with the scholarship for teaching and learning through research engagements. Students are facilitated online in the way knowledge is produced in this discipline and the teaching-learning environment and pedagogy. There is a high degree of practical application of theoretical concepts in laboratories, simulated and real work environments. However, it is unclear as to the extent to which students understand and develop competence in discipline specific knowledge. It is evident that the development of research skills is lacking until third and four year of study in which students are expected to do research projects. It is important that research skills be introduced in the first year of study and act as a scaffold in all years of study as per Luckett’s model [17;18]. Moll’s suggestion of “close coupling between the way knowledge is produced” in the discipline and the way students are educated in the discipline would enable new knowledge in the field of engineering [4;19;20;21].

6 RECOMMENDATIONS AND CONCLUSION

The research aimed to determine awareness and understanding of Industrial Engineering as a field among students in order to understand the factors that might be responsible for the low enrolment and graduation rates. The results revealed that students’ knowledge of the techniques used by Industrial Engineering was better that their knowledge of the types of work Industrial Engineering are involved in, with the latter revealing some confusion among students. Overall though, knowledge and awareness among respondents was good, although efforts can be strengthened to improve this.

The under-enrolments, suggest that more could be done to increase awareness and knowledge about the field more widely and make this field more attractive. It would therefore benefit the department to address any lack of knowledge through various interventions such as the distribution of paper based information booklets to schools to stimulate an interest in the Industrial Engineering field at school level, career days/open days at Unisa and within schools with a focus on Industrial Engineering and e-brochures circulated to applicants and current students through online sources.

As part of enhancing awareness and knowledge of Industrial Engineering, there should also be a drive to use the variety of job prospects available to Industrial Engineering graduates as an incentive to attract students into this field and to also target females into this male dominated field to ensure greater gender representability. The results do not explain the trend in graduation rates which have been low and this is an area which would require a separate investigation. Interestingly, however, 11,0% of respondents had indicated that their choice of Industrial Engineering as a field of study was influenced by it being “easier” than other engineering disciplines. It could be that students have unrealistic expectations or perceptions about the discipline and this could in turn influence their success. This however, would need to be explored in more detail in future studies [22;23;24].

7 REFERENCES
