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EVALUATION OF THE INDUSTRIAL ENGINEERING CURRICULUM RELEVANCE IN THE 4TH INDUSTRIAL REVOLUTION: A CASE STUDY OF GRADUATES FROM A UNIVERSITY OF TECHNOLOGY

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ABSTRACT

With the advent of the 4th Industrial Revolution of artificial intelligence, robotics and internet, South African universities are experiencing a growing demand for Industrial Engineering (IE) graduates capable of fulfilling those expectations. Industrial engineers are trained to assist organizations in productivity optimisation and modernization of manufacturing processes. This research investigates gaps between IE subjects offered in the previous IE bachelor of technology programme at a university of technology and its impacts on the current industry market. A questionnaire was sent to IE graduates and data were collected from consented participants with at least one-year industry experience. A qualitative and quantitative analysis outcome from the 83 IE graduates revealed that 60% of the respondents felt IE subjects and topics included in the curriculum were relevant to their regular duties as work as Industrial Engineers. With the graduates from the new bachelor of engineering technology curriculum already at work, evaluation of the impacts of the new curriculum in comparison with the previous were discussed in this study. The research results revealed an increase in relevance of the industrial engineers in the new curriculum and these students are now better equipped in in information technology, problem solving, data analysis in addition to their already strong industry centredness. However, it was noted that there is more room for improvement in the new BET curriculum in terms of artificial intelligence issues such as data science and big data analysis, which are critical for the 4th and 5th industrial revolutions.

Keywords: Industrial Engineering, Artificial intelligence, Curriculum.

INTRODUCTION

The increasing market competition and the use of technology have forced traditional manufacturing organizations to streamline their operating methods and processes to adopt new and winning methods and aggressive, lean, and cost-saving initiatives (Gibbs and Humphries, 2009). From the second industrial revolution, industrial engineering (IE) discipline contributed to industry development. IE field sought to tame the social and economic tumult that came out as productive activity shifted from hand tools to dedicated machines and from steam to electrical power (Bailey and Barley, 2005). Although along the years, industrial engineers' role worldwide has evolved, according to the Institute of Industrial Engineers (2014), the core of this discipline resides and remains in the conception, improvement and installation of integrated systems of peoples' material, information, equipment, and energy. IE is involved in products, processes, and services, from "hard-core" manufacturing to health maintenance and insurance (Zutshi and Grilo, 2019). Zandin (2005) believes that industrial engineering has experience evolution; the development began in the early 1960s with 'student' being taught subjects such as work-study, method studies, production, layout planning, material handling, and a few financial subjects. Even so the environment of industrial engineering began to undergo changes in the 70's with the elaboration of the era of planning and programming. This transformation led to the revision of the academic syllabi, and the inclusion of additional issues such as restraint systems, textile science, operations research, statistical quality control, and computers and programming (Ngetich and Moll, 2013).

South Africa underwent a trying economic slump from 2008, losing in the process a considerable slice of its manufacturing sector and labour force. Nevertheless, due to its ability to view the 'bigger picture' in a 'systems perspective', Industrial engineering victoriously emerged as a means for trimming unnecessary costs and maintaining a cost-effective business approach (Ngetich and Moll, 2013). Recently, industrial engineering has become a critical and essential value-adding component for business excellence in this 4th industrial revolution time. IE approach and skill is increasingly popular among employers in South Africa. The current Covid-19 pandemic has done little but exacerbate the growing demand for IE graduates and professionals in the face of this unparalleled crisis. With the means of a survey conducted targeting IE graduates, professionals, all participants were employed during the study in different industry sectors in KwaZulu-Natal, South Africa. This study aimed at evaluating the IE curriculum relevance in this 4th Industrial Revolution. With 4th industrial revolution being the bedrock of current and future industry successes, this study investigates the existing gaps between the previous Bachelor of Technology (BTech) programme in comparison with the current Bachelor of Engineering Technology (BET) programme) for a university of technology (UOT) curriculum and Industries requirements. With BET curriculum having produced it first graduates in 2021, with some of them already involved in the Work Integrated Learning (WIL), Qualitative and quantitative analysis targeting key IE subjects (for both current and previous curriculum) as well as the teaching methods.
The objectives of this study are:

- To determine the previous IE curriculum in UOT's relevance to the industries expectations.
- To establish whether IE graduates (alumni) are adequately prepared for the current and future industry challenges.
- To identify flaws in the previous IE curriculum and it impacts to industry expectations.

- Evaluation of the new BET curriculum and assess the relevance on addressed the gap in the previous qualification industry expectations.
- To make recommendations for area of potential IE curriculum improvement to a more industry relevant programme.

LITERATURE REVIEW

The Institute of Industrial Engineers (2014) defines industrial engineering as a field of engineering that is "concerned with the conception, improvement and installation of integrated systems of people, materials, information, equipment and energy. It draws upon specialized knowledge and accomplishment in the mathematical, physical, and social sciences together with the precepts and methods of engineering analysis and conception, to define, predict, and assess the resolutions to be received from such systems". Unlike other engineering fields, Ngetich and Moll (2013) perceived that Industrial Engineering is a wide discipline that applies to any industries and its core principles is adaptable to fit any surroundings.

The works of Fredrick Taylor, who is sometimes cited to as the father of IE, in concert with other leading innovators such as Henry Gant, Frank and Lillian Gilbreth, and Henri Fayol created the initial building blocks of Industrial Engineering (Dastkhan and Owlia, 2009). World War II was also significant to the chronicle of the IE. During the second world war, there was an increasing need to obtain greater efficiency in manufacturing techniques which contributed to the finding of new methods such as time study, work study, methods engineering, operations research and character control, among others. Another focal point highlighting the successful application of industrial engineering techniques is the term "productivity". Productivity is a measure of efficiency of a person or a machine to complete a given task. According to Masin and Vytlacil (2001), several factors lead to productivity, among them the living standards, wage and employment levels or even competitive power.

Universities of Technology (previous) IE Curriculum' industries relevance

Globally, industrial engineering programme in higher education strives to get innovative, current, and cognition-driven engineering programmes that have considerable industry value (Li et al., 2020). A tertiary academic institution in South Africa main mandate is to tackle current and future country challenges in order to influence economic development. Universities of Technology work as the lynchpin of a strong economic system by providing intellectual capacity such as science, knowledge, and excellence. With the growing skill shortages concern in South Africa since the end of apartheid, university curricula are being designed to respond to those apprehensions. UOT graduates need the industry sector for experience and to benchmark with the best practices. For the relevance of both industries and graduates in face of this growing skill shortages in South Africa, UOT's learning should be modern, effective and acclimatized to the 4th industrial revolution trend.

Brook and Oliver (2003) discussed a useful set of characteristics, inherent to a UOT:

- Emphasis on industry developments and modifications
- A curriculum designed around the graduate requirements defined by industry expectations
- Focus on strategic research, applied research into professional pattern;

- Multilevel entry and passing levels for scholars;
- Technological capabilities as important as cognitive skills;
- Concerned mainly with the development of vocational/ professional training.

Industrial engineering curriculum in the UOT was designed in order to address the students' needs and make them more skilled, more able, and more employable. Universities of Technology are more employers-centered and provide constant upgrading through short courses (Du Pré, 2009); their emphasis on work experience as well as their regular communication with employers to assure that the subjects delivered to IE students are still relevant to the industry demands. Universities of Technology use experiential learning, referred to as WIL which is considered as one of the central strengths of a university of technology. As part of a qualification at a UOT, students have to engage in WIL in order to graduate. WIL makes UOT students extremely attractive to future employers as it allows them to apply industrial Engineering principles and techniques under a supervised environment while gaining valuable working experience.

Curriculum requirements and graduate training

In this highly competitive work environment, I.E graduates and curriculum are obligated to be highly competitive in the job market and adapt to the constant changes. Non-traditional industries such as technology and service-related sectors have often been stigmatised as logical destination for IE graduates from traditional Universities, however due the rapid changes, there is an increasing expectation for Industrial Engineer graduated from University of Technologies to also contribute in those sectors (Hamidreza, 2005). The number of Industrial Engineers working outside the traditional manufacturing industries are expected to exceed those working in this traditional manufacturing sectors in the near future. The winner of an economic system rests on how quickly university graduates become productive in industries and make significant rapid improvements. The routine and quality of graduates entering Industry are directly tied to the productivity and growth of an economic system. Industrial Engineering graduates for instance have as the main focus raising productivity by reducing non-value adding operations.

To produce industrial engineering curriculum, the higher education bodies' main goals were to formulate, standardize, and monitor the current and emerging academic and non-academic qualifications (Ngetich and Moll, 2013). The three leading academic bodies in South African involved in the Industrial Engineering curriculum development include the South Africa Qualifications Authority (SAQA) as well as the Engineering Council of South Africa (ECSA) or even the Southern African Institute of Industrial Engineer (SAIIE). Apart from these three main academic bodies, to be added voluntary industrial engineering body specializing on the cognition and skills in the mathematical, physical, behavioral, economic, and management sciences, focused on getting the best practical results that will contribute to the success, prosperity, and institution of wealth in the Southern African economy (Ngetich and Moll, 2013).

IE Curriculum development for the 4th industrial revolution relevance

In recent years, Industrial Engineering profession have been playing an increasing role in non-traditional IE sectors such as in the service sector and in the technology sector. With the economy shifting and leaning more toward the service sector, for instance in the finance, health care, education or information technology, the industrial engineering profession has been broadening its scope in order to effectively contribute to the service area (Balasubramanian, 2010). IE's curriculum moves from its traditional manufacturing to match the current market outlook of the 4th industrial revolution. Today IE curriculum gives future UOT education an opportunity to go beyond manufacturing and engage on every aspect of continuous improvement.

Industrial Engineering and the expectation on the South African Industries

Industrial Engineers, unlike other engineering are better equipped to deal with this new norm especially at the time where most companies' focuses on survival. Among the approach and skills sought include method study for workplace ergonomics, system modelling; linear programming models (graphical & simplex); product conceptualization and process planning for storage and warehouse systems, human action, etc.

According to UNESCO (2014), a well-structured curriculum plays a significant part in establishing lifelong learning competencies, as well as social skills, such as tolerance and respect, managing diversity, effective conflict management, advancement, gender equality, respect of human rights, justice and inclusiveness. A curriculum also gives to the evolution of thinking skills, the ability to formulate informed opinions and the attainment of relevant knowledge that scholars need to use in the context of their surveys, daily life and careers (UNESCO, 2014).

Since the mid-1990s, the outcomes-based accreditation of undergraduate engineering programmes has been under debate (Martin et al., 2005). The same authors further argue that the accreditation should emphasize on the producing graduates that meet the industry need (Heitor, 2008). As highlighted in this research topic, the world is quickly changing and consequently there are rapid changes in the types of industries being formed, industrial engineering programmes require improving their curriculum to train and organize pupils to satisfy the future needs of today's rapidly changing industrial workplace. Established on the impact that a curriculum can take in on the thriftiness, it is essential that universities, particularly universities of technology continually update the curriculum to assure that alumni are better prepared for their work in Industry and other sectors.

Background of Current Curriculum

According to Ngetich and Moll (2013), the previous industrial engineering academic qualifications achievable at the University of Technology, South Africa are the following:

- National Diploma in Industrial Engineering (NQF level 6);
- Bachelor of Technology in Industrial Engineering (NQF level 7);
- Master of Technology in Industrial Engineering (NQF level 9);
- Doctor of Technology in Industrial Engineering (NQF level 10).

While the newly modified industrial engineering academic qualifications achievable at the University of Technology, South Africa are the following:

- Bachelor of Engineering Technology in Industrial Engineering (NQF level 7);
- Honours and Post Graduate Diploma (NQF level 8)
- Master of Engineering Technology in Industrial Engineering (NQF level 9)
- Doctorate of Engineering Technology in Industrial Engineering (NQF level 10)

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Engineering students completing the B.E.T qualification should demonstrate competence in all the following Graduate Attributes indicated below (ECSA Engineering Standard):

- Graduate Attribute 1: Problem Solving
- Graduate Attribute 2: Application of scientific and engineering knowledge
- Graduate Attribute 3: Engineering Design
- Graduate Attribute 4: Investigation
- Graduate Attribute 5: Engineering methods, skills, tools, including Information technology
- Graduate Attribute 6: Professional and Technical Communication
- Graduate Attribute 7: Impact of Engineering Activity
- Graduate Attribute 8: Individual and Teamwork
- Graduate Attribute 9: Independent Learning
- Graduate Attribute 10: Engineering Professionalism
- Graduate Attribute 11: Engineering management

Table 1 shows the mapping of graduate attributes to the modules:

Table1. Qualification – Graduate Attribute mapping

	Module Name	**Semester**	Problem Solving	Scientific & Eng Knowledge	Engineering Design	Investigation	Eng Methods, Skills, Tools & IT	Professional & Technical Communication	Impact of Engineering Activity	Individual & Teamwork	Independent Learning	Engineering Professionalism
			ELO 1	ELO 2	ELO 3	ELO 4	ELO 5	ELO 6	ELO 7	ELO 8	ELO 9	ELO 10
FIRST YEAR	Mathematics 1A	1	D									
	Physics 1A	1	D	D					D			
	Electrical Engineering 1	1	D	D		D						
	Computing 1	1					D					
	Cornerstone 101 (General Education)	1					D	D		D		D
	Mechanics of Machines 1	1	D	D		D						
	Mathematics 1B	2	D									
	Physics 1B	2	D	D								
	Industrial Drawing and CAD	2			D		D	D			D	
	Computer programming and data processing	2					D					
	Academic Literacy	2						D				D
	Strengths of Materials 1	2	D	D		D						
SECOND YEAR	Mathematics 2A	1	D									
	Facilities Planning	1					D		D	D		
	Manufacturing Engineering 1	1					D		D			
	Information System Design	1	D				D					
	Communication for Engineers	1						D				
	Industrial Design 1	1			D				D	D	D	
	Mathematics 2B	2	D									
	Engineering Work Systems 1	2					D			D		D
	Production Engineering 1	2					D			D		D
	Quality Engineering	2				D				D		
	Financial Accounting for Engineers	2						D				D
	Industrial Design II	2	D		D				D	D	D	
THIRD YEAR	Statistics 1	1		D		D						
	Engineering Work Systems 2	1		D			D		D			
	Production Engineering 2	1		D			D		D			
	Operations Research	1	D	D						D	A	
	Management Accounting for Engineers	1						D	D			
	Engineering Management	1							D			D
	Engineering Work Systems 3	2							A			
	Production Engineering 3	2		A								
	Simulation Modelling	2					A					
	Project Management	2						A		A		A
	Design Project	2	A		A	A						

Both previous and current Industrial Engineering curriculum target business efficiency in the design, organization, implementation and any operation of basic or complex function of manufacturing.

RESEARCH METHODOLOGY

This research combines both quantitative and qualitative approaches to research methodology. The subjects targeted from the old curriculum include Production Engineering, Qualitative Techniques/Quality Assurance, Facility Layout/Materials Handling, Costing, Operations Research, Industrial Accounting, Automation, Mechanical Manufacturing Engineering and Engineering Work-Study. The evaluation of the relevance of the new curriculum in remedying gaps and improving industries expectations was then analysed.

Qualitative Methods

Qualitative research involves looking at characteristics or qualities of a subject that cannot easily be reduced to numeric values (Leedy and Ormrod, 2012). The qualitative approach describes the subject/phenomenon in an in-depth comprehensive way. The use of qualitative research methods is to provide superior insight of complex circumstances. The procedure required the researcher to interact with participants to accumulate data that is in the form of questionnaires with open-ended questions and consultations. Version of the information collection and construction of imperative narratives is useful in deducing results where there is no demand to build a statistical principle.

Quantitative Methods

The reason for using quantitative methods in additional to the qualitative methods is to gain explanations and predictions. The quantitative methods procedure requires a collection of data (by means of experiments, surveys and questionnaires) made from a wide sample, that can be easily changed into numbers using statistical techniques.

The quantitative research strategy was applied as the main method of data collection amongst the IE alumni to make an overall statistical view on the curriculum and its relevance to industry. However, there were a few questions asked to gather qualitative feedback from respondents. The numerical data were collected in a form a questionnaire which was administrated by the Project Research students (BTech). The questionnaire used a Psychometric response scale called ‘5-point Likert scale’ with responders’ level of agreement to a statement was based in five points: (1) Strongly disagree; (2) Disagree; (3) Neither agree nor disagree; (4) Agree; (5) Strongly agree.

A sample of 83 IE graduates was made out and analyzed in order to identify the relevance of the previous IE curriculum in the manufacturing and service sector of the South African economy. The new IE curriculum programme has already produced it first promotion of graduates and some are already accumulating some work experiences. In order to get reliable feedbacks and evaluate the new BET in Industrial Engineering, a survey was distributed, targeting employed graduates’ supervisors. The survey sought for supervisors with the background in Industrial Engineering, with at least 5 years of working experience even in supervising trainees. A sample of 25 supervisors consented to participate in the survey. The new IE curriculum feedback helps evaluate the gaps raised from the previous curriculum.

The targeted population comprises of the IE graduates from UoT, all working in Kwazulu-Natal. The choice allows avoiding any type of bias. Another aspect targeted by the research was the diploma qualification from the previous IE curriculum. With the assumption that the diploma qualification is fundamental to the previous IE graduate career growth, this study will look at relevant subjects offered and their significance to the participants overall individual development and industry demands.

Banerjee and Chaudhury (2010) define "sample" as any function of the fully defined population that makes accurate inferences of the whole representation. The sample was chosen randomly and consisted of persons with at least a National Diploma qualification in Industrial Engineering for the previous curriculum, BET qualification in Industrial Engineering for the current curriculum. In order to calculate the sample size, the following information was required:

- The size of the population;
- The desired level of confidence;
- True value for the proportion;
- The desired precision of the estimate.

The desired precision (also sometimes called the allowable or acceptable error in the estimate) is half the width of the desired confidence interval. For example, if you would like the confidence interval width to be about 0.1 (10%) you would enter a precision of +/- 0.05 (5%). The size of the population, in this field, is the amount of IE alumni.
The sample size was calculated using the following formula:

$$n = \frac{Z^2\ x\ \ P(1-P)}{e^2}$$

where, Z = value from standard normal distribution corresponding to desired confidence level (Z = 1.96 for 95% CI), P is expected true proportion, and e is desired precision (half desired CI width). From the above the formula, the results provide a minimum sample size of 73 in order to gain confidence and precision in the results.

Data Collection Instrument

Sürücü and Maslakci (2020) assert that key indicators of the quality of a measuring instrument are the reliability and validity of the measures. The principal data collection instruments used in this study are in a form of a questionnaires distributed by IE B-tech students to IE alumni. The questionnaires were mailed in a strain of either an email or a hard-copy to respondents. The respondents were moved over a week to fill in the questionnaire. The sample size of the target population was 73, however, if more respondents completed the questionnaire, it would add more to generalisability of the results of the study. Once the questionnaire was returned, the students analyzed and summarized the data to reach a particular conclusion based on the findings. Microsoft Excel was the tool utilized to analyze the quantitative questions.

RESULTS AND INTERPRETATION OF FINDINGS

The survey questionnaires were sent, and 83 IE's graduates responded positively. Meaning that the target population is above the minimum sample size (73 respondents). Consequently, this study's results are above the acceptable confidence level. The questionnaires were composed of two aspects, 1) Personal aspects and 2) IE curriculum aspects.

Regarding the personal aspects of the study, the research sought to obtain the gender, age group, current sector of employment and years of industry experience from the respondents. This above information assisted to investigate the reliability and validity of data received. As for the Industrial Engineering curriculum related aspects of the study, the researcher expected respondents to select one of the following answers from the psychometric response scale called '5-point Likert scale': strongly disagree, disagree, neutral, agree or strongly agree. The questionnaire was designed to ensure that they are quick and easy to answer and understand.

Results on Demographics

Personal aspects analyzed in this study include gender, age group, participants current sector of employment and their years of industry experience. Figure 1 indicates that the male participants formed a slight larger percentage of respondents with 58%. This nearly equal opportunity for male and female is encouraging sign for the future of South African economy. Furthermore, Figure 2 shows that the majority of the participants 'Age group' was between the age groups of 25-30 with 62%, while the respondents with smallest percentage were those with age under 25 years old and those with age 45 and above. It was interesting to note that experienced industrial engineers from the age group 45 and above ages are more in consulting companies or hold more senior position at their respective companies. This previous point is confirmed in Figure 3 showing a large percentage of IE graduates being employed in the manufacturing sector. However, IE popularity within the service Industry has been growing in recent years and Industrial Engineers are becoming commoners in the energy sectors, logistics and supply chains, finance and others. As for the number of years of experience, Figure 4 reveals that a majority (63%) of participants having between 1-5 years of experience. This is consistent with the majority age group of participants being between 25-30 years old. The number of participants with over 20 years' experience (2%) is also consistent with the age group of participants 45 years old and above.

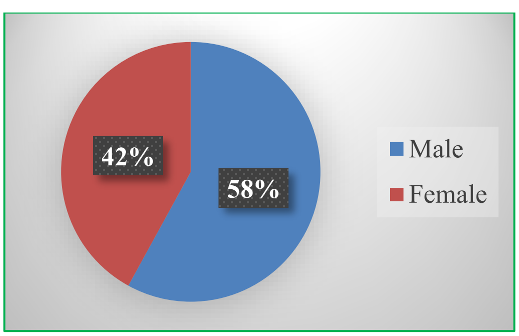

Fig.1 Gender Analysis of participants

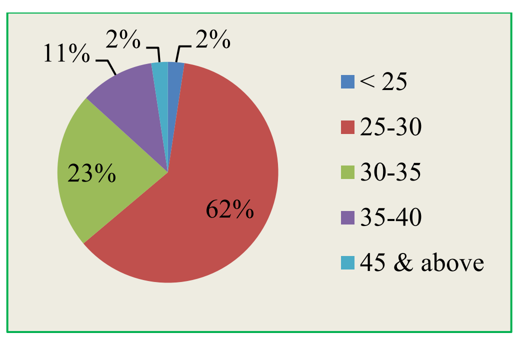

Fig.2 Age Group of Participants

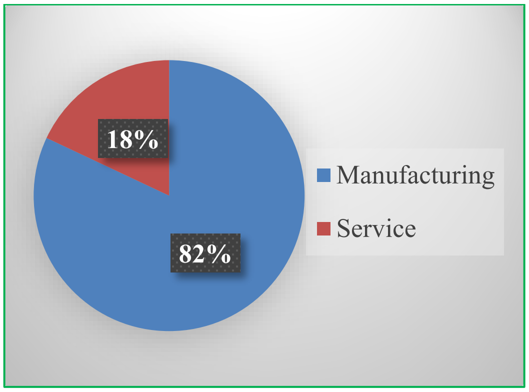

Fig 3 Sector of I.E employment

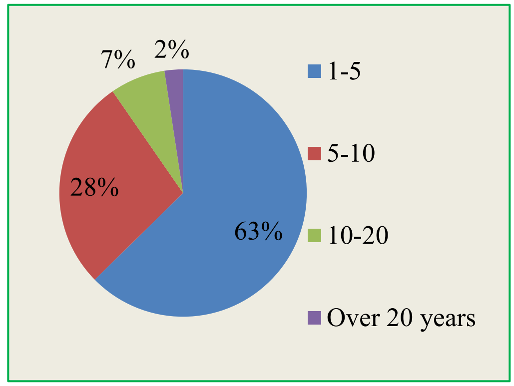

Fig.4 Number of years of experience

In the question of whether IE alumni found their career fulfilling (Figure 5) and on choosing Industrial Engineering career again if given a choice (Figure 6), the findings in Figure 5 reveals that 71% of the participants find IE career largely fulfilling while 15% disagree and the remaining 14% are not sure of what to make of their career. As of choosing IE career again if given a choice, Figure 6 below shows that a good majority of the 83 participants involved in this study "Agree" and "Strongly agree".

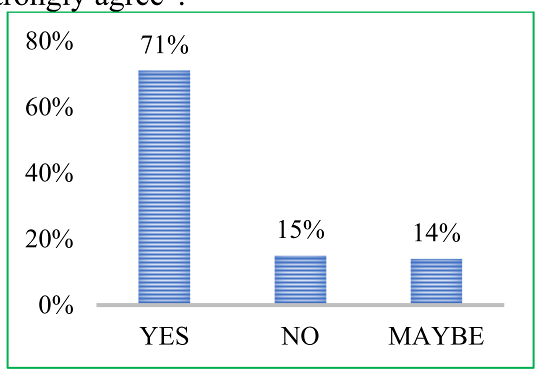

Fig.5 IE Alumni finding career fulfilling

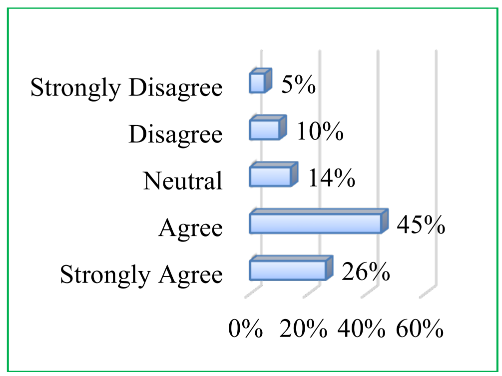

Fig.6 Choice of IE as career again

<u>Results on the relevance of IE curriculum</u>

The questionnaire was broken down into ten key subjects that composed the previous IE National diploma. Specific topics within each subject were selected to indicate how relevant it is to industry practice. The aim of this exercise was to identify the relevance of each subject into the IE curriculum and the industry sector. This study has also taken into consideration I.E alumni' creativity, as Daly et al. (2014) posited 'the ability to engage one's creative process to solve a problem is essential to any engineering profession'. Table 1 lists ten key IE National Diploma subjects, their topics including the percentage of relevance or no-relevance of each topic to industry needs.

To identify each topic relevance, the questionnaire asked the following question to the survey participants for each subject: "Are any of the mentioned items under each programme within your current work or past work functions?" Figure 7 gives a summary of the participant responses to IE Diploma Subjects.

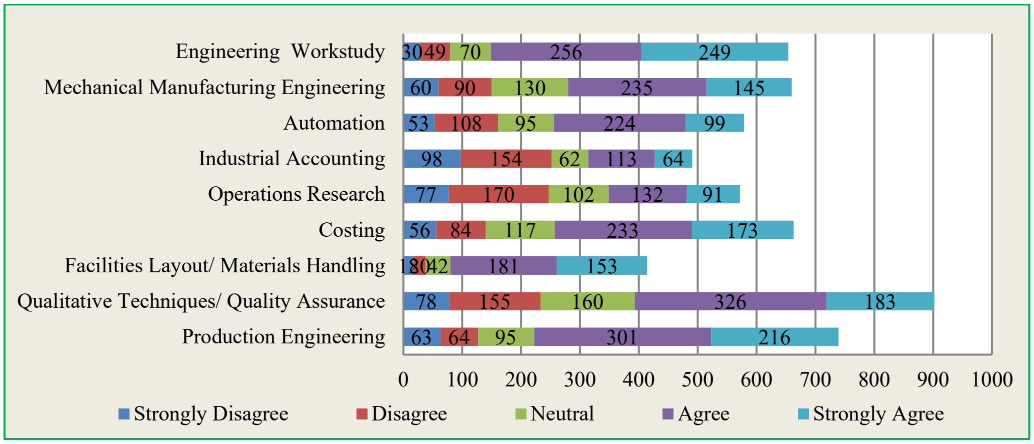

Fig.7 Summary of Participant Responses to I.E Diploma Subjects

Each participant's opinion of the ten subjects was established by using a 5-point Likert scale: (1) Strongly disagree; (2) Disagree; (3) Neither agree nor disagree; (4) Agree; (5) Strongly agree. Among the findings, most participants "*strongly agree*" that "Engineering work study" and "*production Engineering*" subjects and topics are widely applied within their current work or work functions. Meanwhile, a great number of participants "agree" that "*Quantitative Techniques/Quality Assurance*" as well as "*Production Engineering*" subjects and topics are currently applicable in their work functions. As for the "*strongly disagree*" and "degree", subjects such as "*Industrial Accounting*", "*Facility layout and Material Handling*" and "operation research" are among the subjects and topics that do not entirely apply to their regular work portfolio. Finally, the subjects or topics the participants had a "*neutral*" opinion include "*Manufacturing Mechanics*" or "*Costing*".

After determining the participants views on the relevance of previous IE curriculum subjects to their respective workplaces, Figure 8 shows the number of topics per subject and their percentage of: (1) Relevance (computed from Likert scale "*agree*" and "*strongly agree*" responses), (2) non-relevance (computed from Likert scale "*disagree*" and "*strongly disagree*" responses) and (3) Neutral (generated from Likert scale "*neutral*" responses). The findings reveal that 70% of the participants of the following subject "*production engineering*" believe that its contents are relevant to the work they do in Industry. However, 17% found some contents of this subject such as Aggregate planning, product service and design reliability, forecasting techniques, and supply chain management not relevant. As for the subject "*Qualitative techniques*", 40% of the participants agree that Acceptance Sampling was a useful topic in their workplace.

While 37% found hypothesis testing, regression analysis, operational and sample design not relevant. For "*Quality Assurance*" subject, 56% of participants found Quality audit, quality improvement and quality control useful in their daily work as IE's while for 26% of participants, the product acceptance is not relevant. "*Facility layout and material handling*" subject question has revealed that 81% of the respondents found the topic layout procedures and layout process, Product design useful in their IE routine work while 9% found particular topics such as product acceptance not relevant. 61% of topics in the "*costing*" subject is found relevant by the participants.

Those topics included material and inventory control and labor. However, 21% of the topics such as cost/volume profit analysis is not relevant.

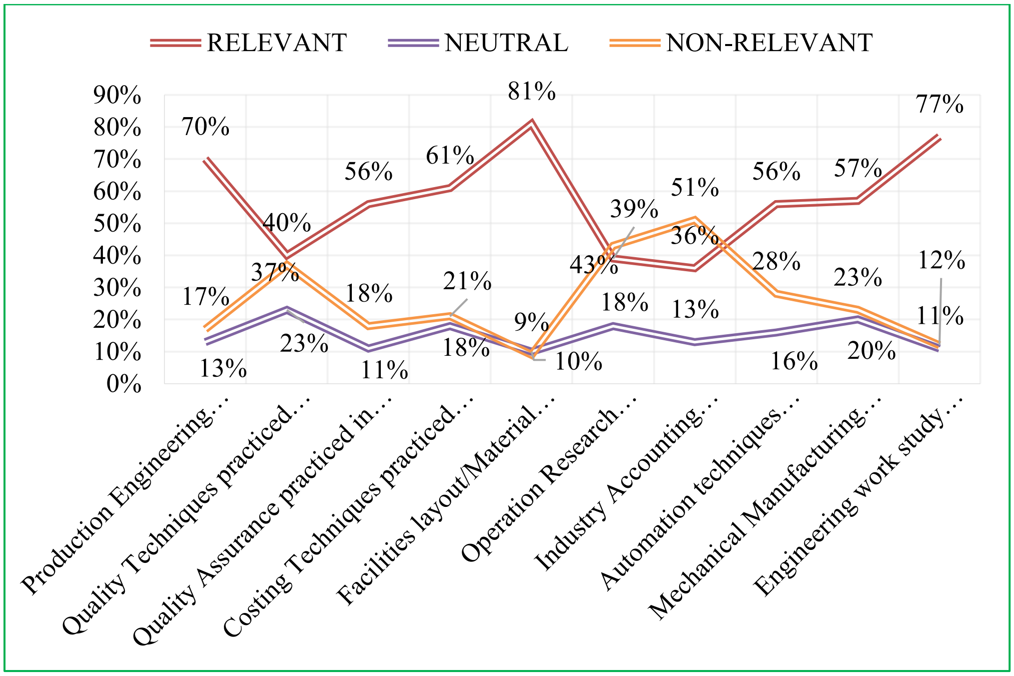

Fig.8 Percentage of Relevance, Non-relevance and Neutrality per subjects

As for the "*Operation Research*" subject, 39% of the respondents found the topics of transportation and assignment models, waiting lines and queuing theory relevant in their regular duty. While 43% found other topics such as linear programming and integer programming not relevant. Only 36% of the respondents found topics from "*Industrial Accounting*" subject relevant; and those topics included financial statements, cash flow and time value. However, 51% found topics such as cash budgets and working capital not relevant. The majority of the respondents (56%) thought most topics of "*Automation*" subject are useful for the work they do and 28% of them was found them not relevant. As to "*Manufacturing Mechanics*" subject, 57% of these subject topics are found relevant to the respondents in their respective workplaces while 23% found aspects of this subject not relevant. Finally, 77 % of Work Study's topics in the "*Work Study*" subject was revealed relevant to their workplace. However, only 12% found aspects of this subject not relevant.

Figure 9 give the summary of the former IE curriculum subjects and topics that survey participants deemed relevant, and the one that are non-relevant as well as where the participants decided to remain neutral. The outcome revealed that 60% of the IE National diploma subjects and topics was viewed by participants as relevant as per Figure 9 below:

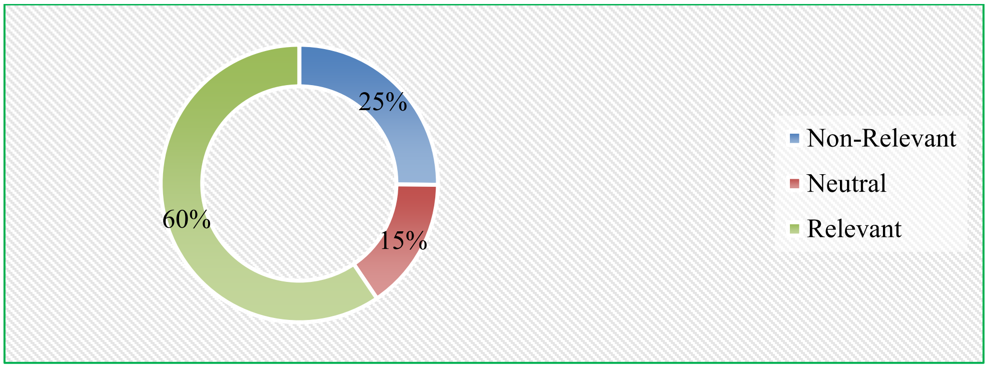

Fig.9 Summary of IE previous curriculum subjects and topics relevance

With the new curriculum having already produced it first promotion of graduates and some are already gaining working experience, 25 questionnaires are sent to both the graduates already at work and their supervisors. Table 2 draws the comparison between the current and the previous IE curriculum subjects. The comparison targets the relevance of both curricula.

Table2. IE Previous curriculum relevance vs current curriculum

	Curriculum	Subjects	Percentage		
			Relevant	**Neutral**	**Non-Relevant**
1	Previous	Production engineering techniques practiced in industry	70%	13%	17%
	Current	Productions engineering	77%	10%	13%
2	Previous	Quality techniques practiced in industry	40%	23%	37%
	Current	Statistics	53%	25%	22%
3	Previous	Quality assurance practiced in industry	56%	11%	18%
	Current	Quality engineering	72%	18%	10%
4	Previous	Costing techniques practiced in industry	61%	18%	21%
	Current	Financial accounting for engineers	48%	32%	20%
5	Previous	Facilities layout/material handling practiced in industry	81%	10%	9%
	Current	Facilities planning	85%	9%	6%
6	Previous	Operation research techniques practiced in industry	39%	18%	43%
	Current	Operation research	70%	11%	19%
7	Previous	Industry accounting techniques practiced in industry	36%	13%	51%
	Current	Management accounting for engineers	31%	30%	39%
8	Previous	Automation techniques practiced in industry	56%	16%	28%
	Current	Simulation modelling	70%	11%	19%

9	Previous	Mechanical manufacturing engineering techniques practiced in industry	57%	20%	23%
	Current	Manufacturing engineering/ industrial design	51%	14%	35%
10	Previous	Engineering work study techniques practiced in industry	77%	11%	12%
	Current	Engineering work systems	85%	5%	10%
TOTAL	Average % of previous curriculum		60%	15%	25%
	Average % of current curriculum		64.2%	16.5%	19.3%

Furthermore, Figure 10 shows the average percentage of previous curriculum vs. average percentage of current curriculum.

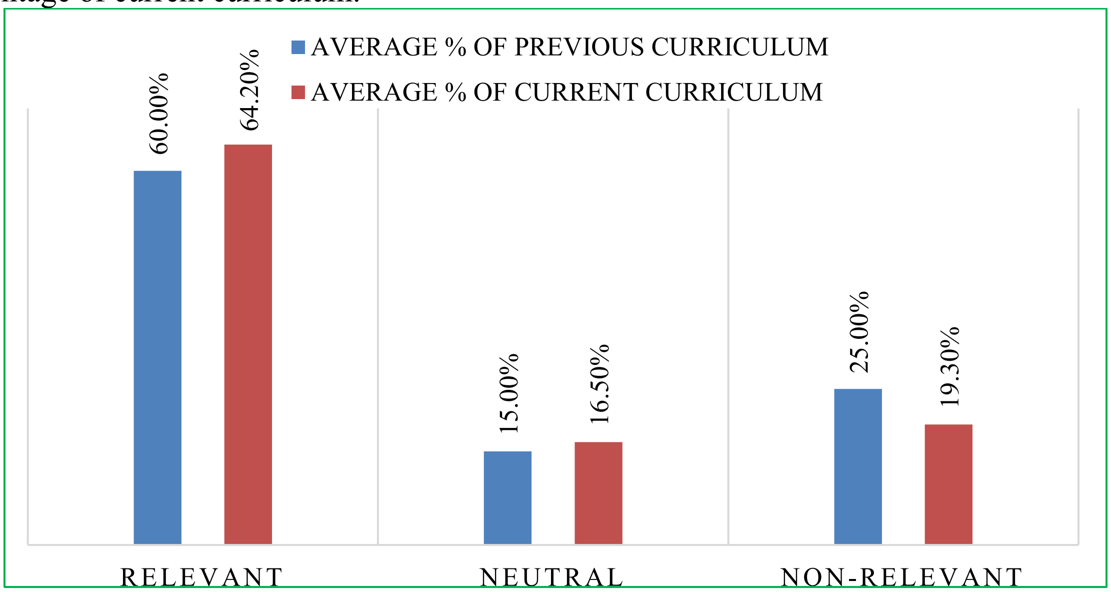

Fig.10 Average % of Previous Curriculum vs. Average % of Current Curriculum

Due to their limited work experience from BET graduates, it is unconceivable that consented participants have already been exposed to every work activity that involves the 10 subjects listed in Table 2. Hence, it can assume that the analysis of the relevance of the IE current curriculum in comparison to the previous in this 4th industrial revolution age will be flawed. To ensure that the new curriculum prepares our students more in the face of this new challenge, 25 graduates' supervisors with the background in Industrial Engineering, with 5 years' working experience in the related field, were surveyed. A question was asked to know "*What is the Graduate Attributes feedback from the graduate' supervisor?*". As mentioned in the point 2.2 and Figure 11, the ten Graduate Attributes are the following: (1) Problem Solving, (2) Application of Scientific and Engineering knowledge, (3) Engineering Design, (4) Investigation, (5) Engineering methods, skills, tools, including information technology, (6) Professional and Technical Communication, (7) Impact of Engineering Activity, (8) Individual and Teamwork, (9) Independent Learning and (10) Engineering Professionalism.

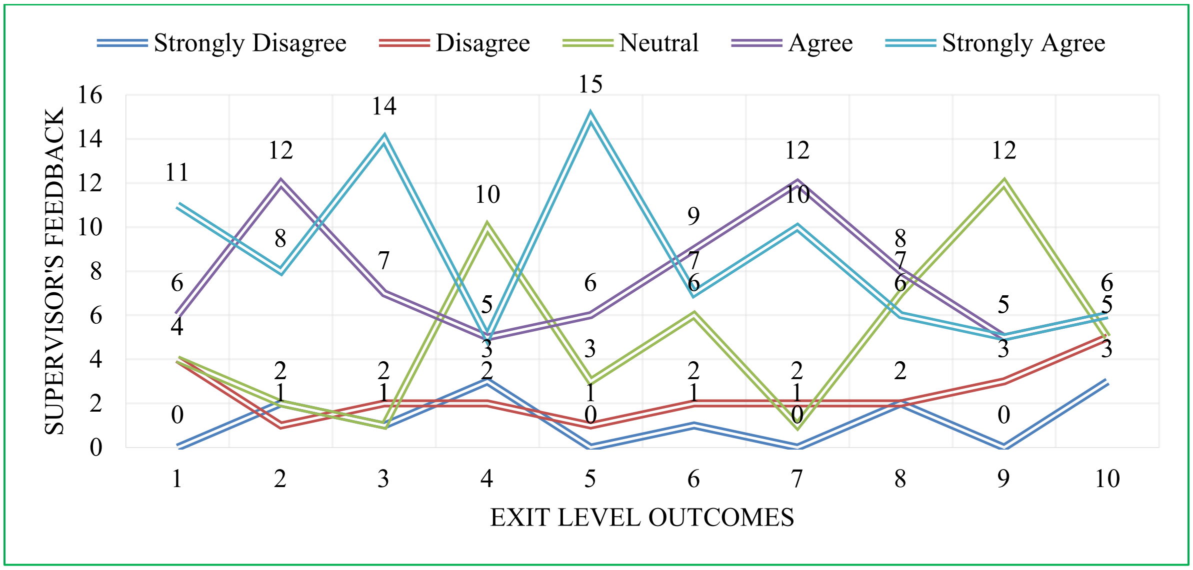

Fig.11 Graduate Attributes from graduated supervisors

Most supervisors in Figure 11 have strongly agreed that the new curriculum has improved the exit outcome (5) on the “Engineering methods, skills, tools, including information technology”.

Discussion on future role of Industrial engineering

It was crucial to use the previous curriculum as a benchmark to evaluate the IE curriculum relevance in the 4th Industrial Revolution, given that the new curriculum was not developed according to the old curriculum. The participants provided positive feedback concerning the topics that were covered in the previous curriculum and its relevance to industry. However, the relevance of curriculum fades mostly due to change of technology and its impact onto industry practices. In this age of artificial intelligence (AI), it becomes imperative that IE curriculum should combine AI with the knowledge of processes, systems, and human factors. A dynamic IE curriculum would yield graduates can maximise productivity, efficiency, and innovation through data-driven decision making, process optimization, robust system design, human-AI collaboration, and workforce reskilling (George et al., 2023).

Given that current technologies generate huge amounts of data, which becomes challenge to interpret and make meaningful decisions, IE curriculum should foster expertise in statistical modeling and data analytics thereby harnessing AI-generated data for informed decision-making. IE graduates should be able to design algorithms that leverage machine learning techniques for analysis of massive datasets, process optimisation, and attainment of operational excellence (Watt et al., 2020).

With the integration of AI into IE curriculum, graduates can identify patterns, predict outcomes, and make data-driven decisions for process improvement. IE gradates should be able to design optimal, robust systems that embrace humans, processes, and technology in areas such as supply chain optimisation, predictive maintenance, resource allocation, and quality control.

The issue of human-AI collaboration has become imperative in this age of fast-changing technologies, IE curriculum must bridge the gap between technology and human factors, thereby enabling effective AI systems utilisation in industrial environments. It is against the backdrop of task automation due to AI that the IE curriculum strengthens the abilities for both humans and machines to identify areas where human abilities can be augmented by AI. In addition, the issue of workforce reskilling becomes imperative, the IE curriculum should embrace capacitating the graduates to identify skill gaps, assess the impact of AI on jobs, and develop new training programs that will assist employees to adapt to new roles and responsibilities in an AI-driven world.

CONCLUSIONS

UOT's have a significant role to play and carry the responsibility of delivering appropriately qualified graduates to the labor market. This research aim was to evaluate the IE curriculum relevance in this day and age industry and service sectors. The analysis of the survey feedback enabled the determination both previous and new IE curriculum relevance. There was a general positive feedback from the participants regarding the topics contained in the previous curriculum and its relevance to industry indicating that IE graduates left the institution adequately prepared for industry. However, the relevance dwindles mostly due to the increase use of big data, technology into industry practices. In order to remain relevant, the curriculum in the BET programme should work hand in hand with industry leaders to ensure that industry needs are met. The research outcomes from the previous IE curriculum revealed a limited exposure to data analysis, the advanced use of Microsoft excel, project managements techniques, an insight into the renewable energy industry, handling of documentation, process changes and many other critical tools used in this 4th industrial revolution age. The research results also revealed an increase in relevance of the industrial engineers in the new curriculum and these students are now better equipped in in information technology, problem solving, data analysis in addition to their already strong industry centredness. However, it was noted that there is more room for improvement in the new BET curriculum in terms of artificial intelligence issues such as data science and big data analysis, which are critical for the 4th and 5th Industrial Revolutions.

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