6th African Engineering Education Association 2016 (AEEA2016) Conference

20 – 22 September 2016
Central University of Technology, Free State
Main Campus, Bloemfontein

Conference Proceedings 2016

AEEA2016

Challenges of Engineering Education in the 21st Century: Creating Sustainable Solutions

Venue: Central University of Technology, Free State, Main Campus, Bloemfontein

Dates: 20 – 22 September 2016

Bloemfontein Campus: President Brand Street Gate	
Street Address	20 President Brand Street, Westdene, Bloemfontein
Entrance to	ZR Mahabane Building Japie van Lill Auditorium
GPS Coordinates	29°07'17.24" S 26°12'56.51" E

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AEEA2016 Conference Sponsor Logos

The Local Organizing Committee would like to recognize the following sponsors:

AEEA2016 Review Process

A formal "*Call for papers*" was first issued during September 2015, inviting anyone to submit a full conference paper, within the identified tracks, to the Local Organizing Committee. These full conference papers were to be between 4500 and 5000 words, using a double column format (10 Font Size, Times New Roman, IEEE referencing standard). Prospective authors had to email these full papers to the official email address of the conference: aeea2016@cut.ac.za. Acknowledgement of receipt was send to the authors, informing them that a double blind-review process would be applied to their submitted full papers.

The full papers were subjected to a double blind-review process, where the author names and affiliations were removed BEFORE the review process starting. Papers were sent to a minimum of two reviewers, with a third reviewer being requested in case of non-consensus between the first two reviewers. In the blind-review process, full papers were sent to national and international academics who indicated online, via a Google Forms page, their willingness to support the review process. A total of 36 reviewers participated in the review process, each reviewing between two and three papers on average. Reviewers were encouraged to provide words of commendation and possible suggestions for improving the submitted paper. This was the only information from the double blind-review process that was sent to the authors, with ALL other information remaining confidential. Reviewers were also asked to judge the full papers on the following criteria:

Familiarity of reviewer with topic * 0 (Not familiar) to 5 (Very familiar)

- How familiar are you, as reviewer, with the topic you are reviewing

Quality of content * 0 (Very poor) to 5 (Excellent)

- Do you deem the paper to be proof of thorough research and knowledge of the most recent debates and literature in this field of study? (e.g.: are the majority of references within the last 10 years?)

Significance * 0 (Strongly disagree) to 5 (Strongly agree)

- Does the paper add value to the engineering education community? (e.g.: will the results be of interest to engineering educators at the AEEA conference?)

Originality * 0 (Strongly disagree) to 5 (Strongly agree)

- Does the paper reflect work that is original or enhance current understanding of engineering education work? (e.g.: does it present additional/new student voices/perspectives regarding the use of educational technology?)

Presentation * 0 (Very poor) to 5 (Excellent)

- Does the paper conform to the guidelines of the conference? (e.g.: IEEE referencing style, double column page layout, standard of English language?)

Will you accept/reject the paper? *

1. Accept with major revision
2. Accept with minor revision
3. Accept as is
4. Reject

Review comments were uploaded online via a Google Forms page and were captured and processed in MS EXCEL. Acceptance emails with reviewer comments were sent to the authors, so that they could revise and improve their papers. Camera ready papers were then received and included in the conference proceedings.

Full papers were accepted under the following tracks:

1. GENERAL ISSUES IN ENGINEERING EDUCATION

- Assessment of engineering education
- Sustainable curriculum design
- Effective methods of training engineering personnel
- Innovations in engineering education
- ICT in engineering education
- Education and industrial training
- Engineering education for sustainable development
- New paradigms in engineering education
- Funding of engineering education
- Project or problem based learning - (Case studies)
- E-learning challenges and possible solutions
- Infrastructures for engineering education
- Scholarship of teaching and learning

2. ACADEMIA/INDUSTRY COLLABORATION IN ENGINEERING EDUCATION

- Industry requirements of engineering education
- Social and philosophical aspects of engineering education and its impacts on the society
- Academia/industry interaction programs
- Management of engineering education in tertiary institutions

3. INTERNATIONAL COLLABORATION IN ENGINEERING EDUCATION

- Transfer and sharing of experience in engineering education
- Recognition of foreign qualifications
- Accreditation systems for engineering programmes
- International mobility of academic staff and students
- Technology linkage between developed and developing countries
- Regional collaboration in engineering manpower development
- Impact of globalization on engineering education in developing countries

AEEA2016 Local Organizing Committee

 Prof Alfred Ngowi	 Prof James Swart	 Prof Yali Woyessa
 Prof Willie Du Preez	 Prof Fidelis Emuze	(Absent) Prof Isaac Ntshoe
 Dr Nicolaas Luwes	 Mr Rangith Kuriakose	(Absent) Mr Daniel Maritz

AEEA2016 List of Reviewers

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A. Van Der Walt

Y. Woyessa

T. Sutherland

J. Swart

AEEA2016 Message from the VC and Principal

Acting Vice Chancellor and Principal Elect: Central University of Technology, Free State, South Africa

Welcome to the 6th Regional African Engineering Education Association (AEEA) Conference! It is indeed an honour and privilege for the Central University of Technology, Free State (CUT) to host this conference.

CUT envisions itself to be a centre of knowledge, innovation and excellence, producing a critical mass of researchers and innovators that directly contribute to prosperity creation. Through its vision, CUT seeks to consolidate its uniqueness and comparative advantage in order to contribute substantively to addressing the developmental needs of the Free State, the Central region, South Africa as a whole, and our continent, Africa. In 2011, CUT celebrated its 30th year of technological innovation, thereby reflecting the University's pursuit of quality education and academic excellence. In its efforts to educate, teach and train students with the aid of world-class technology and an entrepreneurial focus, CUT continues to focus on those values it holds dear, namely customer service, excellence, innovation, integrity and diversity.

A unique manner in which CUT strives to provide academic excellence and diversity is by bringing together academics and industry leaders from across the globe to discuss, deliberate and debate critical matters involving Engineering Education in Africa and the rest of the world during the 21st century.

It is with this in mind that I warmly welcome you to the 6th Regional AEEA Conference at CUT. This conference was previously held at the University of Lagos, Nigeria (2002 and 2013), and the

University of Pretoria, South Africa (2006), bringing together academics from many prestigious universities and industry leaders in Africa and the world. The conference is jointly hosted by the African Engineering Deans Council (AEDC), and is sure to provide a unique sounding board for new and established researchers, Deans as well as for graduate students, as it provides the opportunity for professional socialising, networking and intellectual development.

The objective of this conference is to provide a unique opportunity for researchers and graduate students to network and embrace intellectual development within the field of Engineering Education. It also aims to provide a forum for educators, professional organisations and industry leaders to discuss common problems in Engineering Education. Participants are expected to examine approaches to teaching, learning and curriculum structures that could advance Engineering Education in a resource-constrained environment. Exchange of information, links and collaboration between member nations on the one hand, and the rest of the world on the other hand, will be fostered. The scope of the conference is broad, covering all aspects of Engineering Education, whilst the workshops will focus primarily on the development of academic staff, addressing themes such as using visual aids in teaching and learning, the practical details of student assessment, and the link between industry and the new Higher Education Qualifications Framework (HEQF)-compliant Engineering programmes in South Africa. The increased globalisation of Engineering Education has further provided academic institutions with new opportunities for co-operation in the international arena, by building new, and expanding regional and global networks for Engineering Education.

More than 100 delegates registered for the AEEA2016 Conference, of which approximately 50% are from South Africa; 40% from the rest of Africa; and 10% from abroad, including delegates from Australia, Benin, Botswana, Canada, Ghana, Nigeria and Uganda. 34 of these delegates will present research papers that focus predominantly on Engineering Education research within the Civil Engineering, Electrical Engineering and Information Technology (IT) fields. A number of papers also consider pedagogy, with emphasis on problem-based learning.

Allow me to acknowledge the hard work of the Local Conference Organising Committee, under the leadership of Prof. Alfred Ngowi, and supported by the AEEA, under the leadership of Prof. Funso Falade; the AEDC, under the leadership of Prof. Adagbonyin Obiazi; the South African Society for Engineering Education (SASEE), under the leadership of Prof. Brandon Collier-Reed; and the Global Engineering Deans Council (GEDC), specifically Prof. Hans Hoyer, Secretary-General of the International Federation of Engineering Education Societies (IFEES), and Executive Secretary of the GEDC.

I trust that you will enjoy the South African hospitality during your stay at CUT, in the city of Mangaung, and that you will find the AEEA2016 Conference an inspiring and unforgettable experience.

Kind regards

Prof. Henk de Jager

AEEA2016 Message from the LOC Chairman

Chairman of the Local Organizing Committee

The **6th Regional African Engineering Education Association (AEEA2016) Conference** aims to address the challenges of Engineering Education in the 21st Century, with the intention of creating sustainable solutions. This prestigious conference, which is held every two to three years, is co-sponsored by the African Engineering Education Association (AEEA) and the International Federation of Engineering Education Societies (IFEES).Global and African leading experts and researchers in Engineering Education will gather to share innovative knowledge and sustainable solutions that can enhance Engineering Education on the African continent. The previous conference, held in Lagos in 2013, addressed the theme "Harnessing Scarce Resources for Advancement of Engineering Education" and was a resounding success as it attracted a large number of delegates from different parts of Africa and beyond.

To find sustainable solutions to the challenges of Engineering Education in the 21st Century will require AEEA2016 to provide a vivid forum for discussion and networking between all stakeholders. This will be accomplished by means of scientific sessions and practical workshops facilitated by Engineering Education experts from more than 15 countries.

A total of **48** papers were received, where **37 were ACCEPTED** and **11 were REJECTED**. The first call of papers was circulated on the Internet during September 2015. The second call was made available during February 2016 with the third and final call being extended during April 2016. The major topics included GENERAL ISSUES IN ENGINEERING EDUCATION, ACADEMIA/INDUSTRY COLLABORATION IN ENGINEERING EDUCATION and INTERNATIONAL COLLABORATION IN ENGINEERING EDUCATION. The majority of received papers fell within the first topic, covering general issues in Engineering Education relating to assessment, pedagogy and quality. The papers were subjected to a blind double-peer review process, where the author's names and affiliations were not included. Papers were sent to national and international reviewers who indicated online via a Google Forms page their willingness to support the review process. A total of 36 reviewers

participated in the review process, each reviewing between two and three papers on average. Review comments were uploaded online via a Google Forms page and were captured and processed in MS EXCEL. Acceptance emails with reviewer comments were sent to the authors, so that they could revise and improve their papers. Camera ready papers were then received, and are included in the conference proceedings.

Hand in hand with the desire to encourage the participation of the next generation of engineers in AEEA activities, a students' conference under the auspices of the African Student Forum for Engineering Education (ASFEE) will be held on 19 September 2016 at CUT, just ahead of the AEEA2016 conference. This is the first ever national student forum organized by the Student Platform for Engineering Education Development (SPEED). The South African Society for Engineering Education (SASEE) will also run their annual academic development workshops on 20 September 2016 at CUT, hereby collaborating with the AEEA2016 conference to the benefit of Engineering Education. Furthermore, the African Engineering Dean's Council meeting will be held on 23 September 2016 at CUT, hereby reinforcing their endorsement of Engineering Education on the African continent!

We, as the Local Organizing Committee, eagerly anticipate a stimulating and rewarding conference. May the hospitality of CUT and the AEEA2016 conference prove eagerly rewarding to you!

Prof. Alfred Ngowi

AEEA2016 Conference Program

DAY 1: Monday	**19 September 2016**			
African Student Forum for Engineering Education (ASFEE) coordinated by the Student Platform for Engineering Education Development (SPEED)				
DAY 2: Tuesday	**20 September 2016**			
Time	**Event**			**Venue**
08:30 – 10:30	**Registration (Tea, coffee, juice and muffins)**			**ZR Mahabane**
10:30 – 12:30	**ICT – Using visual aids in teaching and learning**			**ETB 109**
10:30 – 12:30	**AEEA 2016 Workshop**			**Sanlam Auditorium**
12:30 – 13:30	***Sit down Lunch***			**Artrium Hotel School**
13:30 – 15:15	**Assessment – The bolts and nuts!**			**ETB 001 Auditorium**
15:30 – 16:30	**Industry and the new HEQsF compliant engineering programmes**			**Sanlam Auditorium**
16:45 – 18:30	**Conference tour up Naval Hill and onto Bagamoya**			**Bus Tour**
18:30 – 21:00	***Welcoming Dinner***			**Bagamoya**
DAY 3: Wednesday	**21 September 2016**			
Time	**Event**			**Venue**
08:00 – 09:00	**Registration (Tea, coffee, juice and muffins)**			**ZR Mahabane**
09:00 – 09:05	**Prof Alfred Ngowi**	Chairman		**Japie Van Lill**
09:05 – 09:15	**Prof Henk De Jager**	CUT Acting Vice Chancellor and Principal Elect Message		**Japie Van Lill**
09:15 – 09:25	**Dr Thomas Auf Der Heyde**	Deputy Director-General: Research Development and Support Department of Science and Technology		**Japie Van Lill**
09:25 – 09:35	**Prof Hans Hoyer**	IFEES Secretary Message		**Japie Van Lill**
09:35 – 09:45	**Prof Funso Falade**	AEEA President Message		**Japie Van Lill**
09:45 – 10:15	**Prof Yacob Astatke**	Keynote Address	Pan-African Research Collaboration : A Vision for the Future of Engineering Education in Africa	**Japie Van Lill**

10:20 – 10:50	***Tea Break***			**ZR Mahabane**
10:45 – 11:15	**Prof Erik De Graaff (Prof Mona-Lisa Dahms)**	Keynote Address	The Challenge of Responsible Engineering' – Balancing technological advancement, social responsibility and sustainability	**Japie Van Lill**
11:15 – 11:45	**Prof Jian Lin**	Keynote Address	A plan for Educating and Training Outstanding Engineers in the 21st Century	**Japie Van Lill**
11:45 – 12:15	**Prof Otlogetswe Totolo (Prof David Norris)**	Keynote Address	Challenges Encountered in Establishing a new Faculty of Engineering	**Japie Van Lill**
12:15 – 12:45	**Prof Yuan Si**	Keynote Address	Engineering Education in MOOC era	**Japie Van Lill**
12:45 – 12:50	**Prof Funso Falade**	**Launching of African Journal of Engineering Education (AJEE)**		**Japie Van Lill**
12:50 – 12:55	**Prof James Swart**	**Vote of Thanks**		**Japie Van Lill**
12:55 – 13:50	***Sit down Lunch***			**Artrium Hotel School**

Parallel breakaway sessions at the Hotel School

DAY 3: Wednesday	**21 September 2016**				
14:00 – 15:30	**ROOM 107: Big 5**	**14:00 – 15:30**	**ROOM 108: Springbok**	**14:00 – 15:30**	**ROOM 112: Protea**
Session Chair	**Prof. Ninatubu Lema**	**Session Chair**	**Prof. Yali Woyessa**	**Session Chair**	**Dr. Nicolaas Luwes**
Topic	**Engineering Education Assessment**	**Topic**	**Civil Engineering**	**Topic**	**Civil and Electrical Engineering**
Paper ID & Author	**S.O. Ekolu**	**Paper ID & Author**	~~**C. Fapohunda**~~	**Paper ID & Author**	~~**M. Aluga**~~
9 Present	Proposed Method Of Evaluating The Eligibility Criteria For Supplementary Assessments	**1 Absent**	~~The Necessity For The Development Of Sustainable Civil Engineering Curriculum That Matches The Nigeria Societal And Environmental Needs~~	**44 Absent**	~~Impact Of Privatization Of Mining Industry In Developing Countries On African Engineering Education: A Case Study Of Zambia~~
Paper ID & Author	**S.O. Ekolu**	**Paper ID & Author**	**J. E. Yankah**	**Paper ID & Author**	**J. Ssegawa**
24 Present	Cronbach's Alpha Reliability Coefficient In Engineering Assessments – A Preliminary Study On Possibilities And Precautions	**17 Present**	Engineering Education And Marketing Of Engineering Business Enterprise: The Case Of Construction Education	**46 Present**	Measuring The Level Of Maturity Of The Construction Industry To Provide Feedback To Engineering Education: A Case Of Botswana

Paper ID & Author	**S.O. Ekolu**	**Paper ID & Author**	**M.W. Nkomo**	**Paper ID & Author**	**P. Hertzog**
25 Present	Correlation Of Formative And Summative Assessments Results In Engineering Studies	**18 Apology**	Mentoring On Retention Of Graduates Employees In The Construction Sector: A Literature Review	**16 Present**	Student Voices Regarding Practical Instruction In A Solar Energy Course Indicates Student Satisfaction
Paper ID & Author	**J. A. Olorunmaiye**	**Paper ID & Author**	**K.O. Adjei**	**Paper ID & Author**	**K. Ouahada**
35 Present	Influence Of Mode Of Entry On Academic Performance Of First Year Engineering Students In A Nigerian University	**20 Present**	Awareness And Utilization Of Construction Videos In The Teaching Of Construction Technology Courses In Ghana	**41 Apology**	Outcome-Based Module For Continuous Assessments In Engineering Education: Case Study Department Of Electrical And Electronic Engineering Science At The University Of Johannesburg
19:00 – 21:00	***Gala Dinner***	***PPS Presentation!***			**Oliewenhuis**
DAY 4: Thursday	**22 September 2016**				
08:00 – 09:00	**Registration (Tea, coffee, juice and muffins)**				**Artrium Hotel School**

Parallel breakaway sessions at the Hotel School

DAY 4: Thursday	**22 September 2016**				
09:00 – 10:30	**ROOM 107: Big 5**	**09:00 – 10:30**	**ROOM 108: Springbok**	**09:00 – 10:30**	**ROOM 112: Protea**
Session Chair	**Prof. Joseph Ssegawa**	**Session Chair**	**Prof. James Swart**	**Session Chair**	**Prof. Fidelis Emuze**
Topic	**Quality in Engineering Education**	**Topic**	**Information Technology**	**Topic**	**PBL and Pedagogy**
Paper ID & Author	**S.O. Ekolu**	**Paper ID & Author**	**B. Mafunda**	**Paper ID & Author**	**M. Havenga**
10 Present	On Capacity And Quality Issues In Engineering Studies Across Sub-Saharan Africa	**31 Present**	A Review Of The Information System Models For Technology Acceptance	**13 Present**	Engineering Education For Sustainable Development: Embedded Skills In Problem-Based Project-Organized Learning
Paper ID & Author	**P. Baron**	**Paper ID & Author**	**J. Louw**	**Paper ID & Author**	**H. Alinaitwe**
14 Present	The Role Of Context In Decolonising Engineering Curriculums In Proudly South African Universities: A Cybernetic Perspective.	**32 Present**	Extending The Technology Acceptance Model For E-Learning Discussion Forum Adoption	**19 Present**	Advantages And Short Comings Of Using Problem Based Learning In Engineering Education In Uganda

Paper ID & Author	**C. Aigbavboa**	**Paper ID & Author**	**M. Noluntu**	**Paper ID & Author**	**~~J. Katende~~**
21 Present	Conceptual Framework For Enhancing Engineering Education In Ghana's Polytechnics	**37 Present**	Investigating The Low Pass-Rate Of CCNA1 Students At The Central University Of Technology	**47 Absent**	~~Imparting Inductive Reasoning And Information Acquisition Skills To Make Successful Problem Solvers In Engineering Education: A Review~~
Paper ID & Author	**E.E. Matemba**	**Paper ID & Author**	**A.J. Swart**	**Paper ID & Author**	**E. Basson**
30 Present	Preparation Of Internationally Recognised Professional Engineers	**5 Present**	Student Voices Regarding Practical Work Done In A Mechanical Engineering Laboratory Reveals Satisfaction!	**12 Present**	Developing And Teaching A First Year Professional Communication Course At An Engineering School In South Africa
Paper ID & Author	**~~E. Agbenyeku~~**			**Paper ID & Author**	**B. Alabadan**
34 Absent	~~Prospective Inclination Of Research And Engineering Education~~			**6 Present**	Competence-Driven Engineering Education: A Case For T-Shaped Engineers
10:30 – 11:00	***Tea Break***				**Artrium Hotel School**

Parallel breakaway sessions at the Hotel School

DAY 4: Thursday	**22 September 2016**				
11:00 – 12:30	**ROOM 107: Big 5**	**11:00 – 12:30**	**ROOM 108: Springbok**	**11:00 – 12:30**	**ROOM 112: Protea**
Session Chair	**Prof. Henry Alinaitwe**	**Session Chair**	**Prof. James Katende**		
Topic	**Quality in Engineering Education**	**Topic**	**Pedagogy**		
Paper ID & Author	**A. Olorunmaiye**	**Paper ID & Author**	**K. E. Kanyarusoke**		
36 Present	Harmonization Of Engineering Qualifications Through South-South Cooperation In Africa	**48 Present**	Teaching Engineering In Sub-Saharan Africa: The Need For 'Pracademics'		
Paper ID & Author	**~~M. A. Bodude~~**	**Paper ID & Author**	**A. H. Basson**		
40 Absent	~~Challenges Of Effective Training Of Engineering Personnel – Case Study Of Nigerian Technical Training~~	**15 Present**	A Comparison Of Teaching Practices At Some Leading Engineering Faculties		
Paper ID & Author	**~~E. Agbenyeku~~**	**Paper ID & Author**	**~~T. Ofuyatan~~**		
42 Absent	~~Developing Countries And The Need For Building Engineering Capacity~~	**28 Absent**	~~Sustainable Skill Development Through Industrial Training For Engineering Students~~		

Paper ID & Author	**T. Hanekom**	**Paper ID & Author**	~~**E. Agbenyeku**~~		
45 Present	Curriculum Review From The Dual Prism Of Academia And Industry	**33 Absent**	~~Supporting Hands Of A Tutor Towards Activity-Based Education~~		
Paper ID & Author	**G. M. Bubou**	**Paper ID & Author**	**A. Ngowi**		
23 Present	Innovating Engineering Education To Foster Soft-Skills: Challenges And Opportunities	**49 Present**	A Competency-Based Approach to Recruiting and Developing Academic Leaders – A Review		
12:30 – 13:30	***Sit down Lunch***				**Artrium Hotel School**
13:30 – 14:00	**Prof Alfred Ngowi**	**Closure**			**Japie Van Lill**
14:00 – 16:00	**Tour**	**Centre for Rapid Prototyping and Manufacturing**			**CUT**
14:00 – 16:00	**Prof Funso Falade**	**AEEA Annual General Meeting**			**Japie Van Lill**

African Engineering Deans Council

DAY 5: Friday	**23 September 2016**		
Prof. A.M.O. Obiazi	President		**Japie Van Lill**
Prof. P.K. Igbokwe	Secretary General		
Prof. Alfred Ngowi	V.President (Southern Africa)		
Dr Claude Dumfang	V.President (Central Africa)		
Dr Berhanu Demessie	V.President (East Africa)		
There shall be four main sessions on the 3rd day of the AEEA-AEDC Conference. There shall be three technical sessions while the fourth session will be a general meeting of AEDC.			
08:00 – 10:00	**Smart Curriculum for Effective Engagement with Industry**		**Session 1**
Speakers	**Affiliation**	**Topics**	**Moderator**
Prof Sunil Maharaj	Dean of Eng, Univ of Pretoria, South Africa.	a. Curriculum Review from Dual Prism of Academia and Industry	**Prof Emmanuel Ajav**
Mr. Rovani Sigamoney	UNESCO Director, Africa.	b. UNESCO Work Programs in Africa	Chair, Committee of Deans of Engineering & Tech of Nigerian Univs [CODET]& Dean of Engineering, Univ of Ibadan, Nigeria
Prof Ighodalo Osagie	Dean of Eng, Ambrose Alli Univ, Ekpoma, Nigeria	c. Engineering Education for Wealth Creation in Africa	

10:00 – 10:20	***Tea Break***		**Japie Van Lill**
10:20 – 12:00	**Roadmaps and Pathways for Radical Technology Transformation in Africa**		**Session 2**
Speakers	**Affiliation**	**Topics**	**Moderator**
Prof Felix Aisien	Dean of Eng, Univ of Benin, Benin City, Nigeria	a. Overhauling Science and Technical Education at the Primary and Secondary School Levels.	**Prof Peter Kilpatrick**
Dr Theresa Mkandawire	Dean of Eng, Univ of Malawi, Blantyre, Malawi	b. Focused Education and Strategic Planning for Engagement of Technical Graduates in Agriculture, Manufacturing, Extractive Industries and Services Sectors of the Economy.	Chair of Global Engineering Deans Council [GEDC]
		c. Presentation by the next host [2017] of AEDC Summit	
12:00 – 13:00	***Sit down Lunch***		**One on Park Hotel School**
13:00 – 15:00	**Developing Strategic Partnerships and Collaboration in Driving Engineering Education in Africa**		**Session 3**
Speakers	**Affiliation**	**Topics**	**Moderator**
Prof Joseph Afolayan	Fmr Vice-Chancellor,Prof of Civil Eng, Federal Univ of Tech, Akure, Nigeria	a. Developing Intra-University and Intra-National Partnerships	**Prof Tania Hanekom**
Prof Theo Andrew	Deputy Vice-Chancellor & Executive Dean, Durban Univ of Tech, Durban, SA.	b. Collaboration and Partnerships at Intra – Continental Levels	Dept of Electrical, Electronics and Computer Engineering, Univ of Pretoria, South Africa.
Engineer Otis Anyaeji	President, Nigerian Society of Engineers [NSE],Abuja, Nigeria	c. Engineering Education Relevant to Africa's Development	
15:00 – 17:00	**AEDC General Meeting**		**Session 4**

AEEA2016 List of Papers

AEEA2016 Conference Sponsor Details

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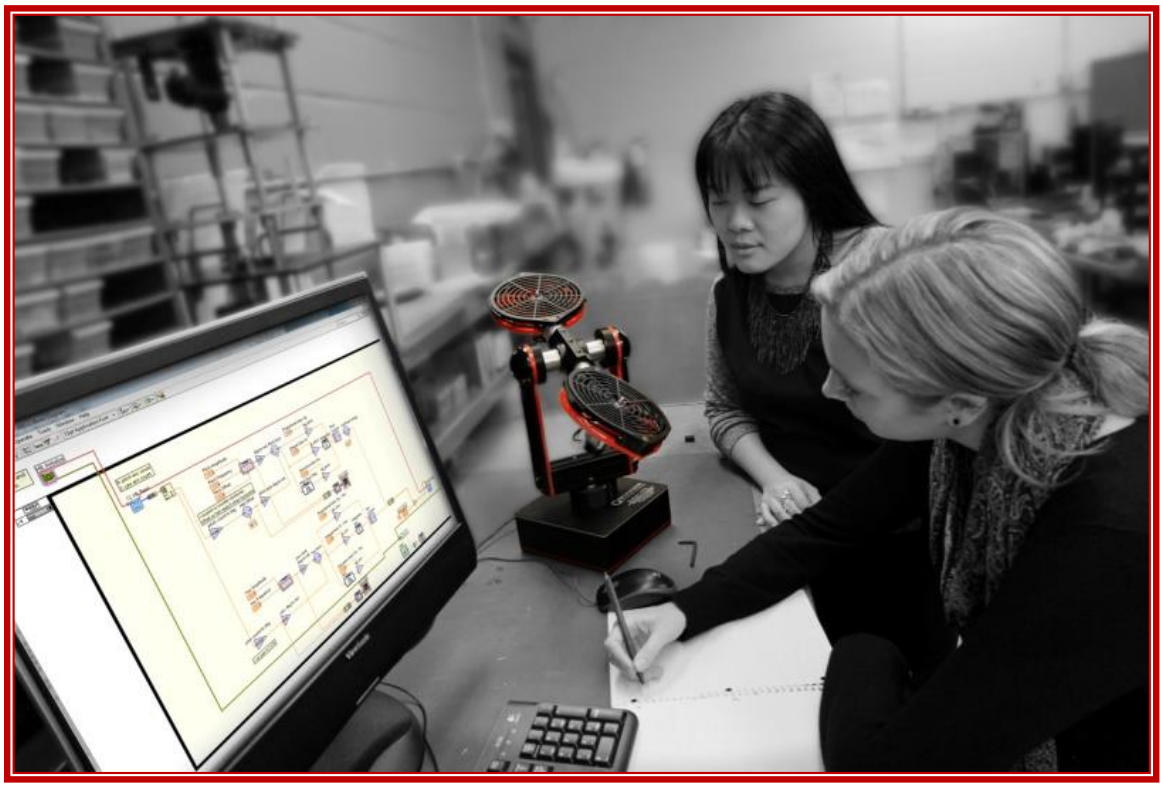

Proposed Method of Evaluating the Eligibility Criteria for Supplementary Assessments

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***Abstract* – During assessments, the results of an examination or test are assigned into a category of pass or fail. In engineering studies and most other disciplines, the pass/fail category is determined from grading of assessments, typically requiring allocation of a quantitative mark achieved by a candidate, in a given module or course program. Institutions have well-defined policies on mark criteria used to determine the pass/fail category. However, quite a challenging issue arises from the category of students whose performance falls within the pass/fail borderline, typically 40 to 51% mark category.**

The marks of students in this borderline category are usually influenced not only by cognitive abilities of the candidate but also by marking errors, and unpredictable factors arising during the period of assessment or examination. Accordingly, there is a group of candidates that are awarded a pass category, that "truly" belong to the fail category, and the converse is also true. As such, there is an in-built error in almost all assessment practices. For example, once a student obtains exactly or just above 50%, they do not often receive a re-test consideration, yet it is possible that the student's "true" score could be in the fail category. So examiners have to embark on a process to separate out those who achieved a fail but could have passed. This is normally conducted by offering a re-test in form of supplementary assessment or examination.

In this paper, it is attempted to review the common sources of errors affecting marking, and to discuss issues particularly leading to re-tests. The *overlapping distribution method* is proposed for use to evaluate the selection of a specific mark cut-off as a required criteria that students must meet to qualify for re-tests. Such an evaluation method can be applied to inform policy on re-tests and supplementary examinations.

***Keywords* – Eligibility criteria, supplementary assessments, marking error, academic performance, reliability, scores**

I. INTRODUCTION

Owing to the high costs of studies at higher education institutions (HEIs), the performance of students enrolled often draws high financial stakes. In most cases in Africa, students finance their studies through the meager incomes of families and through bank loans. In countries such as South Africa, some engineering students can be fortunate to find sponsorships from the private sector industry, usually offered by companies, firms or government corporates. Students who complete their engineering studies, are required to pay back their loans in cash or in kind by working for the sponsor for a period of time. During the period of their engineering studies, stakes are high regarding the performance of students during examinations. Those who fail summative assessment of a module, face the high risk of losing their sponsorship and/or, dropping out of the HEI altogether.

This article focusses on grading of summative assessments with particular interest in deciding the pass/fail categories through re-tests. For this purpose, the overlapping distribution method (ODM) is explored as a potential technique for deciding on the appropriate cut-off mark criteria that students must meet in order to qualify for supplementary examinations.

II. FACTORS AFFECTING STUDENTS' ACADEMIC PERFORMANCE

The issue of academic performance of students at HEIs is a foremost priority matter for all stakeholders of higher education from students and parents, lecturers and professors, to executive management of education institutions. Problems in academic performance of students, relate to a wide array of factors that may impact their results. It is therefore befitting that this area has attracted a great deal of research interest at various institutions globally, as exemplified by the intensity of research publications on the subject [1]-[10]. In Africa, studies in this subject have been done in various countries including South Africa [10], Uganda [5], Nigeria [2]-[3], amongst others.

The academic performance of students not only have financial implications as discussed earlier, but it also affects their graduation. An extensive study by the Engineering Council of South Africa [11], found that for the four-year engineering undergraduate programs offered by HEIs in South Africa, only 30% of first year enrolments graduate after five years, 14% remain within the system usually repeating various program modules while 56% drop out of university without completing their engineering studies. This high dropout rate is an issue that resonates with the high interest among stakeholders, in an attempt to understand its causes, with a view

of improving the current dropout rate. In the broader picture of issues in Sub-Saharan which has the lowest enrolment worldwide, improving academic performance would contribute to increasing the very low number of engineers in the sub-continent. Studies [11]-[13] show that the number of qualified engineers per thousands of the population is very low in Africa, being one engineer for 3166 thousands of the population for South Africa, 5930 thousands for Tanzania and 6373 thousands for Zimbabwe. This number of engineers in Africa is very low compared to other developing countries, such as 227 thousands for Brazil, 681 thousands for Chile.

In a quest to improve academic performance, studies have identified a group of six factors [4,11] comprising:- Student selection for admissions to a HEI, student study habits and interests, institutional support systems, student family and home environment during studies, program structure and curriculum, academic lecturers and instructors. All these factors are experienced by a student at different stages of space and time spent at the university study environment. More importantly, these factors eventually influence the outcomes of the student's academic performance. An attempt to represent the interactions and influences of these factors is shown in Fig. 1 [14]. Some of the factors such as the learning environment are not within the students control but rather under the universities support system. However, these challenges test the student's personal abilities such as persistence etc., to adapt and exploit existing university resources towards his/her performance.

Attempts have also been made to develop conceptual models that explain the pathway leading to student retention or drop out. An example of such a model was suggested by Tinto [15-16] giving a time-based longitudinal framework, leading to the eventual success or failure of the student in the study program, as shown in Fig. 2. Three of these factors that appear to bear defining success are the student's attributes of skills and abilities, prior schooling and the academic program during study. Applying Tinto's model, Bitzer and Trokie de Bruin [17] found that prior schooling does influence a student's persistence and retention rates once at university, with low and average performing students at high school showing over-confidence after joining varsity, a factor which may lead to under-estimation of out-of-class requirements and potentially causing adverse academic performance. Martha's [5] study in Uganda identified performance at matric or higher certificate of education (A-level), socio-economic condition of the family, and quality of the high school studied, to majorly influence academic performance of students once they joined university.

As mentioned earlier, academic lecturers and instructors have a significant role in delivering the academic program and deciding on the pass/fail categories of students. In a study by Alos et al. [4], the factor that was reported to be of highest influence on academic performance among final year students was academic lecturing followed by the student's study habits and institutional support systems. In interpreting these results, it should be kept in mind that cultural factors associated with different demographics and locations of institutions can be of important influence too.

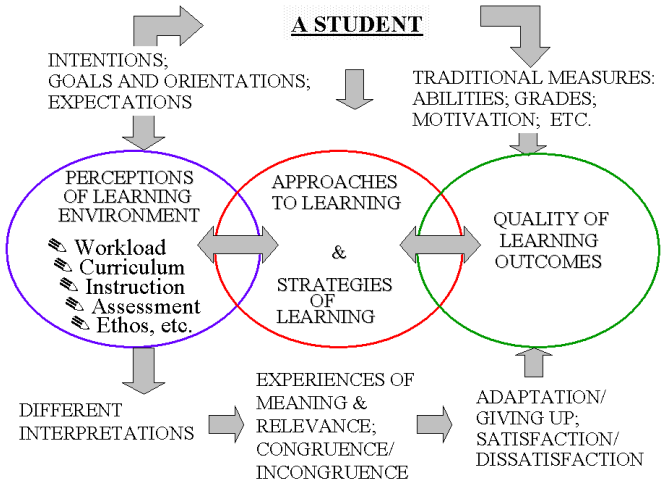

Fig. 1 Student experiences at university [14]

Even within Africa, the student demographics can vary amongst different countries. A case in point is South Africa, which following the end of apartheid in 1994, has embarked on *massification* of education generally, and accelerating growth in higher education, leading to its 16% enrolment at HEIs, the highest among African countries. However, demographic changes in enrolments at HEIs imply that socio-economic factors play a crucial role in the retention of students from previously disadvantaged backgrounds, with factors such as long-distance travel, poor feeding due to poverty, exposure to crimes and violence, all contributing to their academic performance [11].

III. MARKING RELIABILITY

All tests and examinations contain some errors. In the context of this paper, *reliability* is defined as the absence of random error from the administration of an assessment. Theoretically, it is a measure by which the score awarded differs from the true score. But in every assessment, the true score is unknown. Reliability measurement therefore aims at minimizing non-systematic or random errors. The three common sources of errors are discussed in the following [18-19]:

A. Errors in the assessment process

During delivery of an academic course or module, students are taught a given skills set, embedded within the different topics of the module. However, when it comes to assessment, the selection of test items is typically random.

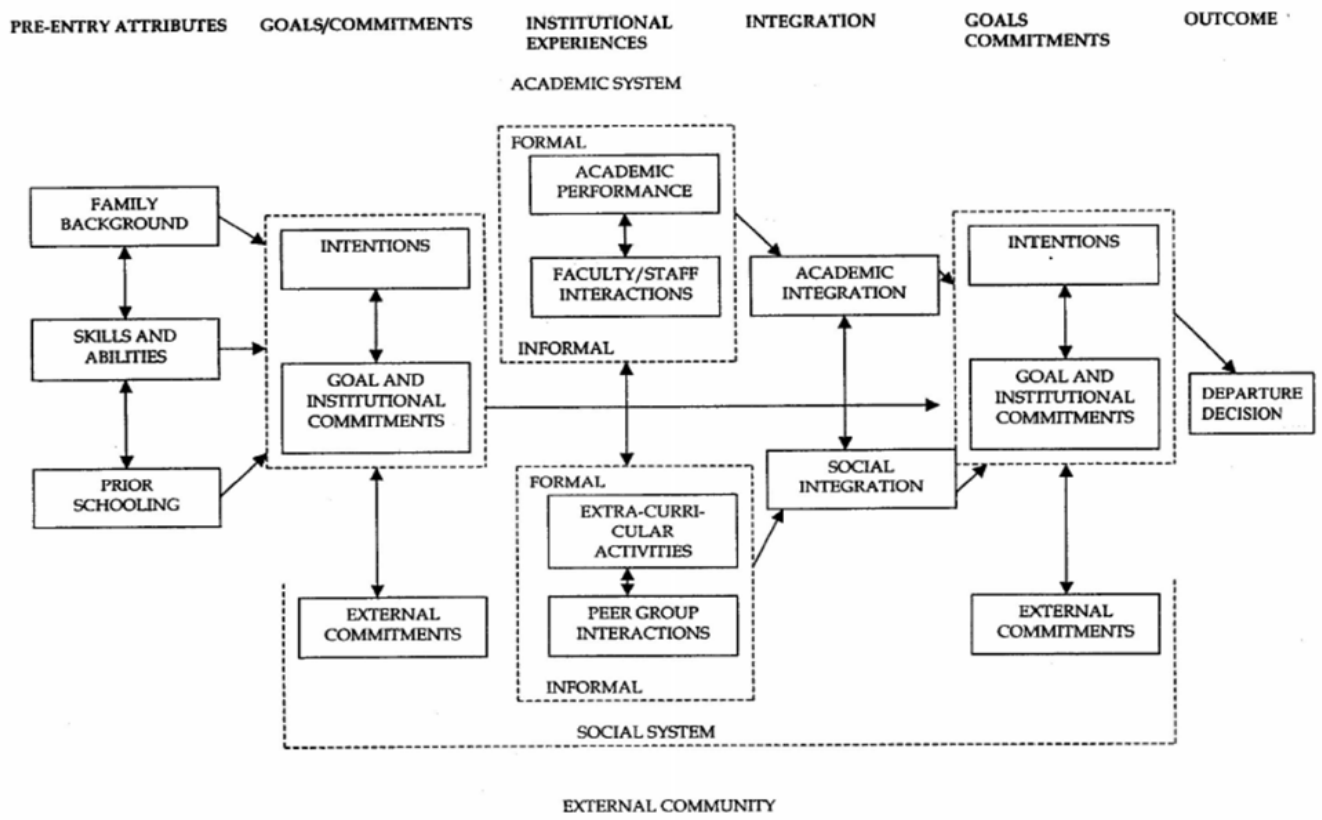

Fig. 2 Tinto's longitudinal integration model of institutional departure [15]-[17]

B. Errors in the assessment process

During delivery of an academic course or module, students are taught a given skills set, embedded within the different topics of the module. However, when it comes to assessment, the selection of test items is typically random. The assumption is that a student is expected to be well prepared in all the skills and knowledge lectured. In selecting the test items, sampling errors are introduced when particular skills are tested while others are not examined at the same level or not given at all. Accordingly, the assessment depends on the limited number of those selected items or topics. This method of conducting tests and exams may tilt the student's performance during a given test event, if for example, a student is better prepared in a particular skills set or topics than in others.

C. Errors in student's consistency

Students are not always consistent to the same level, a trait shared by all human beings. Sometimes, a student may be fresh and upbeat while in other times, he/she can be tired, bored, feeling lazy and sleepy, all arising from an array of various socio-economic factors, environment, and personal habits that also tend to vary on daily basis. Some of these factors could be beyond the students control. Receiving bad news, say on loss of a relative for example, prior to an examination would potentially adversely impact the psychology and mindset of a student, eventually depreciating his/her effort and productivity in the assessment. These factors can also lead to errors such as haste, panic, nervousness, loss of concentration, amongst others.

D. Errors in scoring

Scoring is the domain of academic instructors. Like students, examiners are not perfectly consistent. Errors in grading can be influenced by the type of examination i.e. essay or multiple type questions, and abroad array of factors including candidates writing, fatigue, experience, mood etc., of the examiner.

IV. MEASURING SCORES

The commonly applied approach to score determination, the *classical reliability theory*, expresses the score received by a student statistically as [19,20]:

$$X_{it} = T_i + E_{it}$$

Where X_{it} is the score that a student, i receives during a given test or exam event at time, t. T_i is the student's theoretical "true" score, and E_{it} is an error or noise responsible for the difference

between X_{it} and T_i. The error value is determined statistically. Minimising, E_{it} ensures that the assessment is accurate as X_{it} converges towards, T_i.

V. OVERLAPPING DISTRIBUTION METHOD

Following the scoring of scripts, some marks will fall between the borderline of a pass and a fail, such as marks between 40 and 51%. Usually it becomes quite subjective to decide which of the students would be given a pass and which would be awarded a fail at the first assessment opportunity. The common practice at HEIs is to give supplementary examinations, as a means of acknowledging the underlying system and random errors, and attempting to eliminate their effect on the student's academic performance.

Different HEIs exercise different policies on deciding the candidates that would be considered eligible for re-test or supplementary examinations. In South Africa, the minimum cut-off mark required of students to qualify for supplementary exams tends to differ from one institution to another; it is usually 45, 40, or 35% depending on the institution. In most institutions, the rationale used to decide on the minimum cut-off mark does not seem to be clear but it appears to involve factors such as large class sizes, increased work load for academic instructors, ability of the students to pass given a second chance, amongst others.

A. Research problem

As mentioned above, two groups of students emerge after conducting script marking or summative assessment. These groups may be named the "Fail" (F) Group and the "Pass" (P) Group. Among the F-group, there are students who should belong to the P-group and vice versa. These are usually students whose marks are borderline, in the range of say, 40 to 51% and may be referred to as "Supplementary" (S) group. Fig. 3 is a statistical representation of overlapping distributions, giving relations between the three groups. By deciding on the cut-off mark for students who may qualify for supplementary examination, the real issue is an attempt to identify the S-group, correctly. The question then arises, what should be the correct cut-off mark to use: 45, 40, 35% or none?. In this investigation, the ODM is proposed for use to evaluate the cut-off mark criteria.

B. Theoretical success rates

A statistical procedure was conducted, by fixing the reference mark to the typical pass value of 50%. The fail group distribution was then adjusted to different cut-off mark levels of 45%, 40%, 35% to represent the S-group. The probability that an S-group of students based on each cut-off mark level, will achieve a pass grade during supplementary exams, is then determined.

For purposes of theoretical evaluation, the error value used was taken from the recommendations of SABS 0100-1 [21] which assigns the standard deviations of 5, 6 and 7 to good, average, and poor degree of control, respectively. Using E_{it} = 5, the relations based on normal distributions were plotted for 30, 35, 40, 45% mark cut-off and probabilities of passing were determined relative to the 50% mark. Figs. 4 and 5 give the probabilities that the S-group of students who obtained 30, 40% and 35, 45% overall assessment mark respectively, will pass supplementary examination.

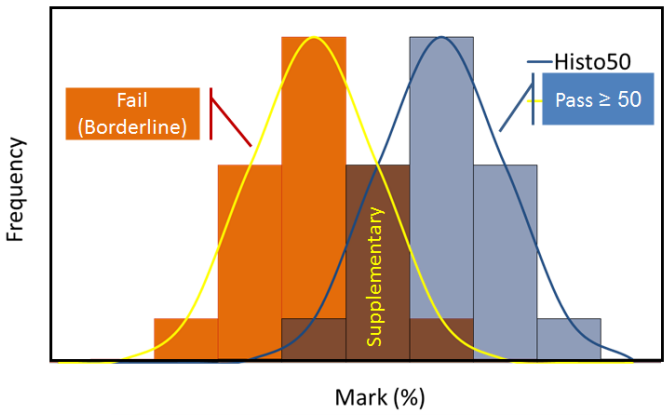

Fig. 3 Relations between the fail, pass and supplementary groups

The ODM shows that for students having a mark of 45%, six (6) of 10 students who sit supplementary exams would be expected to pass. Similarly, three (3) of 10 students who obtain 40% overall mark, may pass supplementary exams. For students with a mark of 35% , only one (1) of 10 students may be expected to pass supplementary exams, while no pass at all can be expected of students with ≤ 30% mark. The analysis implies that students with the cognitive ability to pass supplementary exams should attain an overall mark of at least 35% from formative and summative assessments. But since the proportion of this S-group that pass supplementary exams is low (10%), the criterion may only be worth considering for large class sizes, such as over 300 students. Rather, 40% criterion appears to be suited for small and medium size classes.

VI. CONCLUSION

Academic performance of students, leading to their success or dropping out of the university study programs depends on a broad array of factors. In Sub-Saharan Africa, the accelerated expansion of education to accommodate students of different backgrounds implies that a varied range of socio-economic factors play a major role. Within academic institutions, factors also exist, that would impact students' performance in a highly varied manner. These issues all account for the mark received by the student in a given module or study program during (an) assessment event(s). Within the mark is an in-built systematic and random errors.

Offering supplementary exams, serves as a means by which the influence of these errors on a student's success or failure, is resolved. However, there is no clear method of appropriately deciding which students deserve to undergo the supplementary

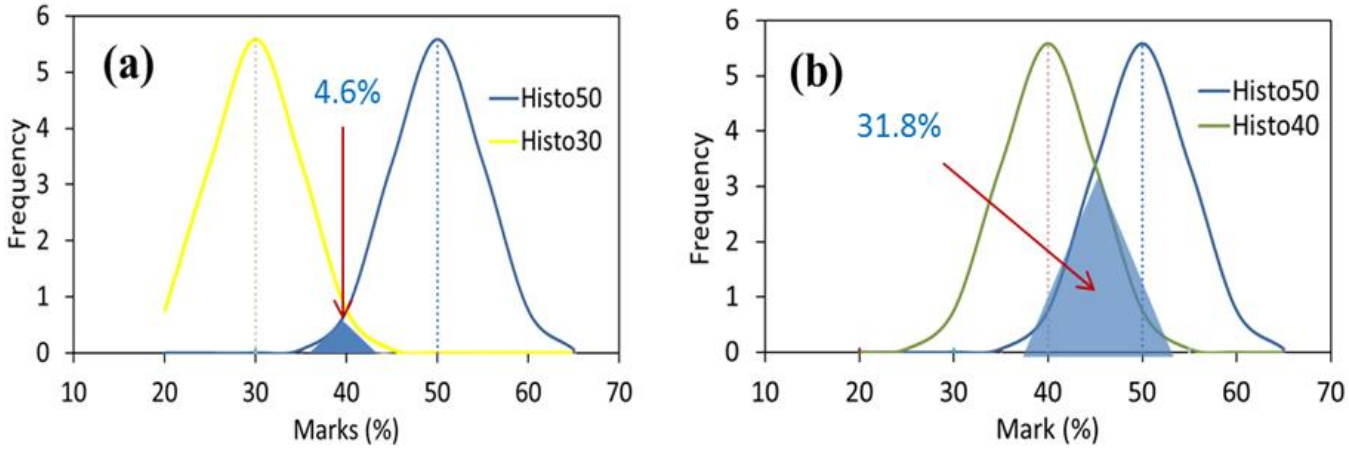

Fig. 4 Probability of students passing under (a) 30% limit and (b) 40% limit criteria for S-group

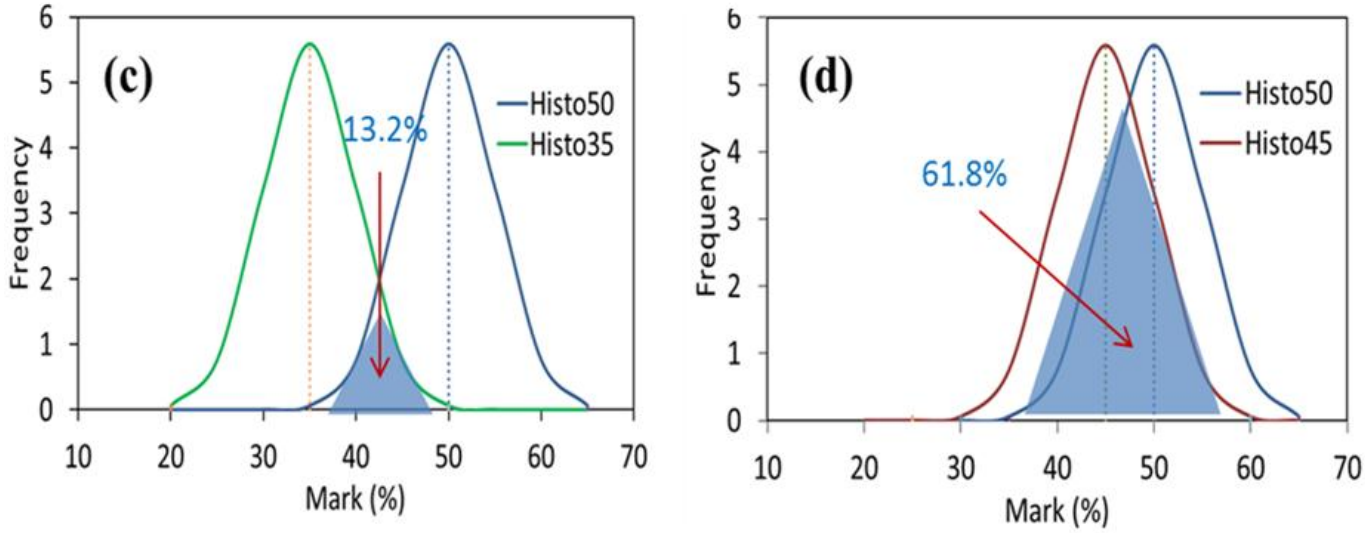

Fig. 5 Probability of students passing under (c) 35% limit and (b) 45% limit criteria for S-group

exam. Accordingly, the policy of most HEIs on eligibility criteria for supplementary exams is often subjectively determined.

In this study, a statistical concept is explored, referred to as the *overlapping distribution method*. It is demonstrated that the method can be used to shape policy on the minimum cut-off mark requirement that students must meet in order to qualify for supplementary exams, based on their potential to achieve a pass.

It is found that students obtaining as low as 40% exam mark would have a potential to pass with 30% of them being able to pass. For an exam mark of 35%, only 10% of students would be expected to succeed in supplementary exams while no pass would be expected for students who obtain 30% exam mark or lower.

The analysis indicates a minimum exam mark of 35% and 40% as suitable cut-off criteria for large and small classes respectively. Although the analysis is theoretical, it underscores the approach as a potential statistical method, which may be used to guide HEI policy on the minimum requirements needed to qualify for supplementary exams.

VII. FURTHER RESEARCH

The ODM statistical concept, which is introduced in this article, has the potential to be developed further as a prediction method for determining success rates in supplementary exams, which in turn may be valuable in shaping policy guidelines of HEIs. Further research is needed to examine the method using historical data from courses or program modules. One of the important aspects requiring research is determination of error, calculated as root mean square (RMS) value, along with validation of the proposed ODM using the *classical reliability*

theory to compare predictions and actual recorded historical data.

ACKNOWLEDGEMENTS

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Cronbach's Alpha Reliability Coefficient in Engineering Assessments – a Preliminary Study on Possibilities and Precautions

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***Abstract* - This paper attempts to apply the Cronbach's alpha to engineering studies. There is hardly any available literature or research on application of this method to engineering course assessments. Alpha coefficient is commonly used in psychometric tests, as a measure of estimating internal consistency. The data used in this preliminary study consisted of five modules taught over five years by different instructors.**

It is found that alpha reliability coefficient values were generally 0.4 to 0.7 but others gave low or negative alpha values which raises the need for precautions. These preliminary findings highlight an underlying potential regarding estimation of reliability in engineering assessments using alpha coefficient but further research is needed to understand how the values determined, relate to internal structure of the assessments.

***Keywords* – Cronbach's alpha, summative assessment, reliability coefficient, validity, internal consistency**

I. INTRODUCTION

Engineering studies at higher education institutions (HEIs) are carefully constructed to follow highly structured curriculum to progressively provide learning and knowledge over a planned period of study from entry to completion stage of mastery. The full study program is a complex structure typically comprising subsets of knowledge areas covering basic sciences, mathematical sciences, engineering sciences and design while complementary skills such as computing etc. are spread across different stages of learning to provide support skills. These knowledge areas are built within academic modules taught at different stages of the program, with lower level modules typically serving as pre-requisites to higher level modules, implying the increase in module difficulty towards higher levels. The instruction of each module is conducted following a Teaching–Assessment Cycle (TAC), shown in Fig. 1 [1], and done across the semester. According to TAC, the instructor conducts continuous assessment of learning acquired by students during the course of instruction. This requires conduct of formative assessment typically in form of assignments, tests and projects. Formative assessment is intended to inform the instructor of the effectiveness of his/her instructional methods and accordingly adjust, if necessary. More importantly, the results of formative assessment enables students to improve their learning progression.

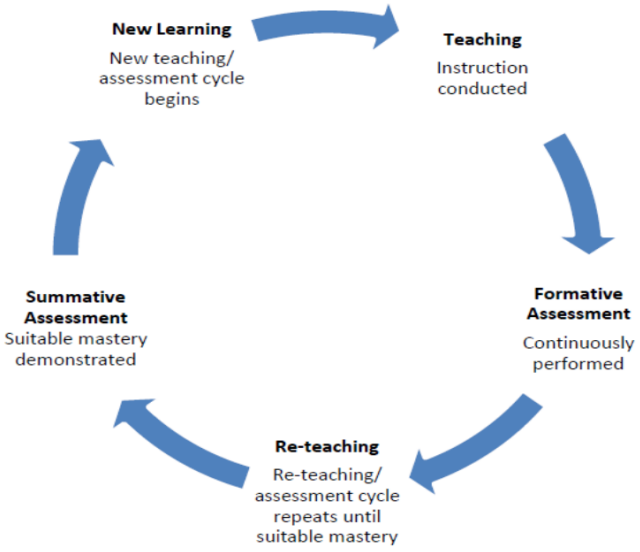

Fig.1 Teaching–assessment cycle [1]

The modern instruction methods used at HEIs are informed by *constructivism*, a theory of human learning which advances the concept that humans learn effectively by experiencing and interacting with the elements within their learning environment. In the process, the minds of individuals form new understanding by comparing the newly observed or experienced knowledge with the present understanding s/he has about the subject. This is followed by replacing the present understanding with the new knowledge or rejecting the new understanding in favour of the present knowledge. The use of different teaching practices are intended to align with the constructivist theory, thus, the constructivist class in engineering studies would typically be interactive and student-centred while the instructor conducts moderation. Such engineering classes involve students to actively engage in discussions, projects, field trips, experiments etc. as opposed to the traditional non-constructivist class at which the instructor is

authoritative and directs the module instruction rather than moderating the learning process. Non-constructivist instruction may strictly follow the textbook approach with tight adherence to a fixed curriculum [2]-[4].

In engineering study programs, marks obtained from formative assessments typically contribute to the final mark. Accordingly, it is often the case that formative assessment marks obtained by students would influence his/her preparation towards summative assessment. Often, students are expected to achieve a minimum requirement in formative assessment in order to qualify for summative assessment. As lecturing continues alongside formative assessment, the instruction of different knowledge components or topics of the module are scheduled such that students are expected to master the knowledge domain, by the time lecturing for the module is complete. It is this level of mastery which is assessed through summative examinations.

Summative assessments are generally high stakes exams for most students as it strongly contributes to the failure or promotion of a student to the next level of the study program. While weighting of summative assessment is only a proportion of the final mark, typically no less than 50%, it is a final opportunity for the student to progress. Students who have shown weakness during formative assessment aim to raise their academic performance level during the final examination. For most students who finance their studies through loans or sponsorships, failing a final exam may mean loss of sponsorship while the funding expenditure of their studies increases, if a student has to repeat the module. Accordingly, instructors hold the responsibility to ensure that summative assessment of a module has adequate levels of *reliability* and *validity* as measures of the knowledge areas covered during the module instruction. Reliability and validity are two different concepts that refer to 'precision' and 'accuracy'. Considering a bathroom scale, or example, if the correct weight of a person is 70 kg but the scale reading gives 55 kg, each time the measurement is made, then the scale is reliable but inaccurate, implying that the results are invalid [1].

This consideration is important as it ensures that students are not disadvantaged by exams that may be unintentionally skewed towards particular dimensions while neglecting others. In the fields of education and psychology, measurement of reliability is conducted using psychometric tests. Such tests are not commonly encountered in engineering studies and research, apart from perhaps some rare questionnaire type surveys or evaluations. This paper is an exploratory attempt to use reliability measurement approaches that are often employed in psychometric tests, to consider how they may relate to assessment of engineering modules. The study is limited to the Cronbach's alpha coefficient method, subsequently discussed. It is applied to summative assessment results of civil engineering modules followed by interpretation of the results obtained.

II. RELIABILITY

A. Classical test theory

All test measurements contain errors. The Classical test theory, recognizes that each test taker or examinee has a *true* score, upon which measurement error is added to give the observed score or mark. Hence the classical test theory [5-6], can be written as

$$X_i = T_i + E_i \tag{1}$$

Where X_i is the score/result obtained by a particular test taker i, during a given test measurement or exam event. T_i is the test takers theoretical 'true' score, and E_i is an error responsible for the difference between X_i and T_i. According to the Classical test theory, reliability is defined as the ratio of variance of true score/mark to variance of observed score /marks and is conveniently written as given in equation 2

$$r_x = \frac{\sigma^2_T}{\sigma^2_X} = 1 - \frac{\sigma^2_E}{\sigma^2_X} \tag{2}$$

Where r_x is reliability of the observed score/result, and σ_X^2, σ_T^2, σ_E^2, are the variance of observed score/result, variance of true score/result, and variance of error respectively. In practice, however, the true score is unknown, making it impossible to theoretically calculate reliability. For this reason, reliability is estimated using test measurements.

B. Internal consistency measurement

Cronbach's alpha is one of the most frequently used methods of estimating internal consistency reliability. The alpha formula is written as:

$$\alpha = \frac{N}{N-1}\left(1 - \frac{\sum_{i=1}^{N} \sigma_i^2}{\sigma_T^2}\right) \tag{3}$$

Where, N is the number of test items or questions, σ_i^2 is the variance for each test item, and σ_T^2 is the total variance. Cronbach's alpha can also be written in an alternative standardized expression as:

$$\alpha = \frac{N.\bar{C}}{(\bar{\nu} + (N-1).\bar{C})} \tag{4}$$

Where, N is the number of test items or questions, $\bar{\nu}$ is the average of all variances of the test items, and $\bar{C}$ is the average of all covariances between the paired test items. Equation (4) resolves the problem of test items measured using different units [7]. The Cronbach's alpha method can be used in tests for both dichotomously (non-continuously) and polytomously (continuously) scored items, the former being 'agree /disagree',

'right/wrong', 'correct /incorrect' type of responses, while in the latter, responses entail ascendency/descendency in agreement i.e. attitude scale such as 'agree', 'strongly agree', 'disagree', 'strongly disagree'. In applying Cronbach's alpha to dichotomous tests, the responses are assigned binary (0,1) numerals for computation. For polytomous responses, the level of Likert scale is defined based on the number of items, such as a five level scale: 1 = 'strongly disagree', 2='disagree', 3=undecided, 4='agree', 5='strongly agree' [7].

III. ASSESSMENTS IN ENGINEERING STUDIES

In considering the potential application of internal consistency reliability measurement in summative assessments, it is crucial to take into account the nature and structure of assessments in engineering studies, and how they relate or conflict with the assumptions employed in reliability methods, specifically the Cronbach's alpha coefficient used in this study. The critical concepts requiring detailed consideration in structuring of summative assessments in engineering studies are the *inter-relatedness of test items/questions*, *dimensionality, and homogeneity of the test/assessment* as a whole. In psychometric tests, the primary purpose of internal consistency test is to measure the association that exists between different test items or questions, such that each item contributes significantly to the same knowledge domain or base being assessed. As earlier mentioned, engineering program studies involve learning the diverse knowledge areas of basic sciences, mathematical sciences, engineering sciences, design and synthesis. These knowledge areas are usually compartmentalized as components of different modules taught over the duration of a four year bachelor's undergraduate degree. For example, a structural design module would involve knowledge areas of:- basic sciences (materials, physics, chemistry), engineering sciences (structural analysis, physics, maths), design (conception, imagination, creativity, use of code procedures, maths). While the primary construct is engineering design mastery, it cannot be attained without the knowledge areas that are pre-requisite to its mastery. Accordingly, it is necessary for the assessment of a module to evaluate different knowledge areas as part of the design knowledge domain, in order to ensure validity or representatives of the course content. These knowledge areas that are embedded within the structural design knowledge domain can be considered as sub-tests.

In summative assessments, the test items/questions are selected randomly across the full set of module topics and knowledge areas. It should also be noted that module topics are presented as building blocks, so that knowledge areas covered in earlier topics would be needed in the topics presented at later stages towards knowledge domain mastery. This example illustrates how highly structured the typical engineering modules can be, while ensuring inter-relatedness as a critical requirement. As mentioned in the foregoing, summative assessments have to be *valid* and have to accordingly, involve multiple outcomes. As a result, most test items are essay type questions, each of them covering different concepts or knowledge areas and would normally be divided into sections. For example, one question on beam design can examine basic science (materials), engineering science (structural analysis, maths), and design (conception, technical procedure, maths). Another question on column design would examine similar or different knowledge principles from the beam question but this time, the knowledge area is applied to column design. Therefore, inter-relatedness between the test items can be expected with respect to knowledge areas. But because these knowledge areas are diverse, it is possible that different test items may be used to measure different skills, which renders the test assessment to be heterogeneous both in the type of knowledge areas assessed and in the level of item difficulty. It can be appreciated that examiners in engineering assessments use test items of different difficulties across the assessment but may or may not maintain the same score /mark allocation for each test item. Also associated with item difficulty is the length of test item/question. A summative assessment may use questions of different lengths and that require different time periods to complete. Accordingly, different marks may be allocated to different test questions based on their difficulty and time required to complete the item. This too brings heterogeneity into the assessment. For most engineering modules, however, it is common practice to try as much as possible to provide test questions of same mark allocation. It is also common to introduce variations of balancing out the presence of difficult test questions by including a relatively easier question(s) so as to give the test taker (student) a comprehensive assessment overall.

Some engineering modules are structured to cover two or three different knowledge domains. For example, a module on strength of materials may be divided into two parts presenting material science and mechanics. In such modules, the test questions for material science can be completely unrelated to those in mechanics, making the assessment inherently heterogeneous. In assessing such modules, it is common to divide the assessment paper into sections, each section covering test items of a different knowledge domain e.g. material science, mechanics domain, amongst others.

IV. PRELIMINARY STUDY

A preliminary study was conducted using results from summative assessments of BEng/BSc degree in engineering. Data were taken from five modules of civil engineering study program. The modules designated as S414 and S415 was a structural engineering course that was offered at different academic years for fourth-year students, M215 was a strength of materials module for second-year students, S423 was third-year civil engineering theory course, and S312 was construction materials course for fourth-year students.

The class sizes for each module varied from 56 to 79 students, except one module M215 which had 15 students. This range of classes generally fall within the category of small to medium size classes [8]. There is no strictly standardized

grouping of class sizes, so various researchers typically apply different ranges of class size groupings in their studies [8]-[10]. For purposes of this study, class sizes with student numbers under 20 = small, 20 to 90 = medium, over 90 = large [8].

Summative assessment marks from final exams were used in this investigation. Heterogeneity of the class groups is evident in their assessment results, a sample of which are shown in Fig. 2 for modules S415, S423, S423. The results show normal distribution behaviour, which represents the typical characteristics of a properly composed group. It is also seen that the average performance of the class groups lies between 40 to 65%, depending on the module. Similar observations are exhibited by the other modules, M215 and S312.

In this study, alpha reliability coefficient was determined for each module of the same test length i.e. same number of questions but the test items would not be of the same level of difficulty. All assessments /exams consisted of four essay type items or questions, each being worth 25 marks. It should also be mentioned that all questions were compulsory.

V. RESULTS AND DISCUSSION

In this study, Cronbach's alpha was estimated using the formulae given in equations (3) and (4), for both the 25-Likert and 5-Likert scales. The 5-level Likert scale was defined as: 1 = 0 to 5 marks, 2 = 6 to 10 marks, 3 = 11 to 15 marks, 4 = 16 to 20 marks, 5 = 21 to 25 marks.

Table 1 and Fig. 3 show the effects of Likert scale level and the two Cronbach's alpha formulae on reliability estimations. When the different equations (3) and (4) were used, it is seen that for all positive alpha coefficient, equation (4) consistently gives reliability values that are similar or slightly higher than those determined using equation (3). But the difference is small, occurring at $1/100^{th}$ of magnitude and is negligible. Similarly, changing the Likert scale level from 25 to 5, generally gave a small decrease in alpha coefficient. The reason for this behavior is not clear, however, the difference is small and negligible, occurring at $1/100^{th}$ of magnitude.

As seen in Fig. 3, a majority of the modules gave Cronbach's alpha falling between 0.40 to 0.70 which is consistent with interpretation of $0.50 < \alpha < 0.80$ as moderate reliability [11]. In engineering studies, high reliability is not desirable as it depletes course content and diminishes validity of the assessment. Some modules, however, gave alpha coefficient that is lower than 0.40 and even negative values. As given in Table 1, Module S415 gave negative alpha coefficients ranging from -0.04 to -0.31, while the coefficients for M215 were positive but also generally low. S423 gave the highest coefficients with a value of 0.66.

While the negative alpha coefficients do not make sense, it is observed that all modules that gave $\alpha < 0.30$ had low inter-item correlation coefficients of less than 0.20, which indicates that these modules had test items that had very small inter-relatedness. Modules with low or negative alpha coefficient do not necessarily imply flawed assessments but could mean that these modules had some items or topics that were completely independent of others, as discussed earlier.

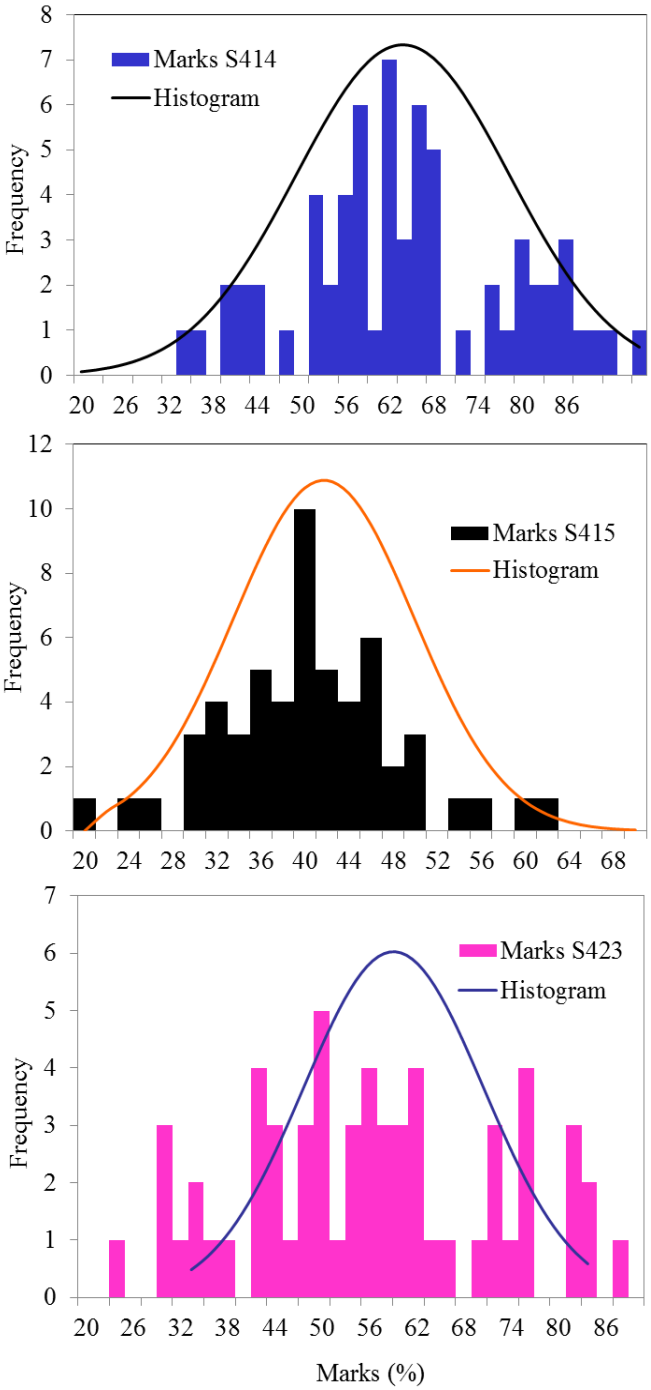

Fig. 2 Summative assessment marks for engineering modules S414, 415, 423.

Accordingly, there is need for precaution in interpreting the alpha coefficients, when applied to comprehensive test items. Also, alpha coefficients usually apply to measurements involving a large number of test items, suggested to be at least

20 direct questions. It is interesting to note, however, that the method shows robustness by giving good response to a small number but comprehensive test items typically used in engineering assessments.

TABLE 1
ALPHA COEFFICIENT CALCULATED USING DIFFERENT FORMULAE AND LIKERT SCALES

Module	Class size	alpha, 25-Level Likert			alpha, 5-Level Likert		
		Eqn 3	Eqn 4		Eqn 3	Eqn 4	
		α-coeff	Item corr	α-coeff	α-coeff	Item corr	α-coeff
S414	65	0.44	0.18	0.47	0.41	0.15	0.42
S415	56	-0.18	-0.04	-0.19	-0.31	-0.06	-0.31
M215	15	0.2	0.07	0.23	0.23	0.08	0.26
S423	60	0.64	0.32	0.66	0.6	0.29	0.62
S312	79	0.51	0.21	0.52	0.51	0.21	0.51

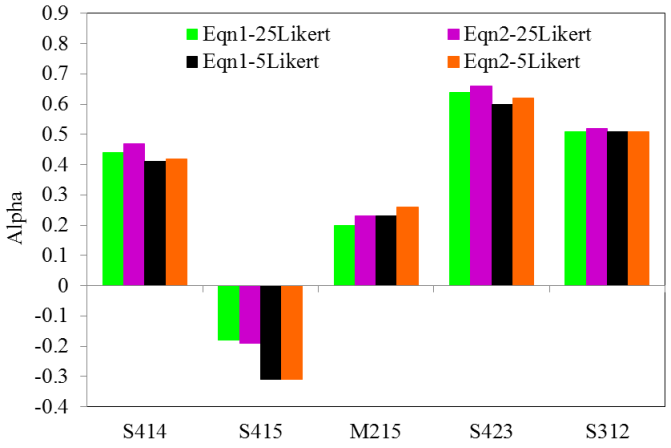

Fig. 3 Comparison of alpha coefficient calculated for 25 and 5-Likert scales

VI. CONCLUSION

A preliminary study was conducted to explore the possibility of using Cronbach's alpha to estimate reliability of summative assessments in engineering bachelors degree programs. It was found that despite the heterogeneity and small number of test items in engineering modules, the alpha coefficient, gave estimation of reliability coefficients to be between 0.4 to 0.7 but it also gave low or negative coefficients for some modules. The factors responsible for the low /negative alpha in some modules are not clear but appears to be associated with the inter-item relatedness.

The Cronbach's alpha method also shows robustness demonstrated by its good response to a small number of test items which are comprehensive questions, the type commonly used in engineering assessments or exams. Further research is needed to understand how alpha coefficients relate to the internal structure of comprehensive test items/questions.

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Correlation between Formative and Summative Assessment Results in Engineering Studies

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***Abstract* - This paper attempts to study the relationship between results of formative and summative assessments. Generally, there is limited research work available in this subject, most especially relating to engineering education. The study is conducted using data of modules lectured to undergraduate civil engineering students over a period of 10 years. It consists of data sets for 409 students under nine (9) assessment events of various modules.**

It is shown that a strong direct relationship exists between semester results and final marks achieved by students. The study found that students that underperform during formative assessments tend to do better in their exams to improve their final marks. The converse is true of students that obtain high semester marks. These findings have the potential to be developed into prediction models that could enable use of formative assessment results for summative purposes. However, further research is needed to expand these findings towards modeling.

***Keywords* – Prediction model, formative, summative assessment, semester mark, examination mark, final mark, weighting**

I. INTRODUCTION

Assessment of educational activities in higher education institutions (HEIs) is an extremely essential part of learning which has the interest of all stakeholders. The stakeholders to learning can be divided into two categories: (a) those internally , provide packages of pedagogical tools employed in the learning process, interact with students in and outside of class, may be role models to students as they strive to master the subject matter. Instructors also assess the progression of students during the course of study and adjust their instruction towards improvement of learning, give final assessment of students mastery of knowledge, evaluate and recommend on the student's ability or inability to progress. However, regardless of the calibre of instructors and academics of a HEI, the learning process can be seriously jeopardized in the absence of appropriate resources including academic materials and library, well-maintained lecture halls and classrooms, instruction technologies including projectors, videos, electronic platforms for upload of e-book and course materials. The provision of these critical resources are ensured by administration of the institution. The administration along with academics of a HEI are largely responsible for the quality of involved in the learning process including students, lecturers and instructors, administrators of HEIs, (b) those external to the learning process but have vested interest in its outcome i.e parents, industry. To students, the results of assessments are the basis for judgment of their learning progression and is therefore used to determine promotion to the next level of study. In the long-term, assessment results are recorded in academic transcripts and become an indelible information of individuals history which usually have influence throughout his/her career. Parents have a direct and an enormous interest in the performance of students, for they are an investment of the family. All prior learning of students from primary education to tertiary level is attained through the guidance and sacrificial support of parents, it be financial, emotional, psychological support etc. Infact, it is the parents and families that deliberately pursue the education of learners as a matter of responsibility to well-being of the young, naïve learner. Completion of a study program by a student, culminating into his/her graduation, is often a milestone in the students life, which is marked by celebration of the occasion, of which parents are usually the most jubilant along with the graduand.

The quality of learning offered to the student depends largely on the HEI, which is the paradigm of instruction and learning environment for which lecturers and the institutional administration are crucial players. Mastery of the study subject is drawn from the quality of instruction, for which the calibre of academic staff is indispensable. It is the instructors that construct the curriculum of the study program, decide on the appropriate level of course materials learning attainable, quality of graduands and brand of the institution, which in turn has influence on employability of its graduands. The industry which employs graduates has interest in the quality of future employees. Consequently, HEIs often liase with industry to include the perspective of industry into the learning process. Some ways in which this is achieved include incorporation of industry led Advisory Boards within the departments of HEIs, use of industry experts as external examination moderators in summative assessments etc, amongst others.

Typically, during the course of study in any given semester or academic year, there is continuous assessment of modules through assignments, project and practicals, tests. This formative assessment is allocated an appropriate mark prior to final exam or summative assessment. The purpose of this paper was to examine the relationship between the performance of students during formative assessment and their results during

summative assessment, with a view of potentially predicting overall academic performance from formative assessment results.

II. LEARNING OUTCOMES IN ENGINEERING STUDIES

A. Learning outcomes

In most HEIs that offer engineering undergraduate study programs, the success or failure of students in their study programs is judged through the employ of formative and summative assessments conducted at the Departments where the study program is offered. Learning outcomes in engineering studies are pre-defined according to program accreditation requirements, usually set by the relevant governing professional body. In South Africa, for example, the Engineering Council of South Africa (ECSA) [1] which is a signatory to an International Accord recognizing engineering programs in 17 different countries, places a demand on HEIs offering accredited engineering study programs to meet specific learning outcomes. The HEIs are therefore required to measure these learning outcomes based on evidence which demonstrates their attainment at exit level. In engineering studies, the knowledge areas covered in a four-year curriculum would include basic sciences, mathematical sciences, engineering sciences, engineering design and synthesis which form the core knowledge and skills, while generic or transferable knowledge consists of computing, information technology and other complementary studies selected at the discretion of the Department.

At exit levels, the competencies attained by students have to be demonstrated by satisfying several outcomes some of which include problem solving, applied scientific knowledge, engineering design, ability to conduct engineering procedures and investigations as core competencies, while generic competencies include professionalism, technical communication, lifelong learning ability, teamwork abilities, and awareness of the impact of engineering in society [1]. Evidently, effective assessment of these learning outcomes require conduct of both formative and summative assessments at different levels of the study program. For example, a student's ability to conduct engineering procedures and methods, would be assessed through coursework experiments and practicals, while technical communication and/or teamwork would be assessment through laboratory and design projects etc. These forms of assessments fall under the formative category. It should also be considered that the type of assessment influences the manner by which students direct their effort and level of academic performance. Assessments which count highly to the final grade marks are taken more seriously and with greater commitment than those with low or no weighting to final grades [2]-[5]. In most engineering studies, while formative assessments may consist of several components such as assignments, laboratory projects and class tests; summative assessments are usually a single final examination event. It is common practice in engineering studies that the results from formative and summative assessments contribute equally, to the final mark awarded. This approach compels students to direct their study efforts rationally to both the formative and summative assessments with clear understanding of implications of the results from each assessment type. Instructors also face the challenge of developing effective assessments that truly measure the learning outcomes. In the literature [6]-[7], attempts have been made to define various kinds of criteria that would be used to determine effectiveness of assessments including use of conceptual models.

B. Formative and summative assessments

In the modern educational system, there has been growing interest in understanding the relationship between formative and summative assessments including the possibility of using formative assessments for summative evaluations [8]-[12]. Jain et al [13] reported an existence of a statistically significant relationship between formative and summative assessment marks. Although Carrillo-de-la-Pena [14] did not report any mathematical relations between formative and summative assessments, they found that performance of students in formative assessments was an indicator of better performance in summative assessments. They attributed this relation to the feedback received from formative assessment which in turn causes students to get more effectively engaged in their preparation for summative assessments. Other researchers [15] have reported similar findings.

III. METHODOLOGY

This investigation, which is conducted to study the relationship between summative and formative performance of undergraduate engineering students, is based on data of nine (9) examination events for modules lectured by a single instructor over a 10-year period. The modules consist of structural engineering, construction materials, and civil engineering theory, taught to civil engineering and construction management students in their third and fourth years of study. As seen in Table 1, the class sizes were of small to medium size, ranging from 18 to 86 students, giving a total of 409 data sets. The table also gives results of the semester mark and the final mark awarded after considering final examinations results. The final mark for the C47-module consisted of 30% weighting for semester mark and 70% weighting for examination mark. In all the other modules, weightings for the semester and examination results were 50% each. It is seen that the average semester mark and final mark are quite close, being 57% and 61% respectively. Also, their standard deviations are similar, giving respective average values of 10 and 11 for the semester and final mark results.

Further statistical characteristics of the academic performance of students are given in Fig. 1 for some of the modules. The results in the figure apply to final marks for the modules. Evidently, all the final results exhibit normal distribution characteristics, which is typical of a heterogeneous class of student. All other modules give similar characteristics

as in Fig.1, regardless of class size and academic performance of the class.

TABLE 1
ASSESSMENT RESULTS FOR ENGINEERING MODULES

Module name	Class size	Semester results		Final results	
		Mark	Std dev	Mark	Std dev
S14	69	61.4	9.1	58.0	8.0
C31-11	86	60.9	7.7	60.0	8.7
C31-09	60	59.6	7.8	60.0	11.0
C31-07	42	62.3	9.6	52.1	12.3
C40-11	48	58.1	9.6	67.8	12.2
C40-08	40	55.7	11.8	58.1	14.3
C47-11	24	54.6	9.5	63.4	9.4
C47-08	22	39.5	10.7	42.7	10.3
C47-06	18	60.2	8.4	52.6	11.9

IV. COMPARISON OF FORMATIVE AND SUMMATIVE ASSESSMENT RESULTS

In this investigation, it is intended to determine if there exists any definitive relationship between formative assessment results of students and their performance in summative assessment. The final marks are calculated from the weighting of semester marks and final exam marks. For most modules used in this investigation, a weighting of 50% was used for each component. The relationship between the semester (SEM) mark and the final marks have been plotted for all nine (9) data sets (Table 1), as shown in Figs.2a and 2b. It is interesting to note that upon plotting of semester mark against the final mark achieved by students, a strong and significant relationship between the two sets exists. Generally, students that perform well in formative assessments also do so in final assessments.

Regressions have been applied to the plots in a bid to establish empirical relationships. Both the linear regressions and power functions have been plotted for each data set. It can be seen in Figs. 2a and 2b, that the R-squared values are quite significant, ranging from about $R^2 = 0.5$ to 0.8. However, in all cases, it is clear that the trendline does not follow the line of equality, regardless of its position above, below or upon the equality line. It is evident that students that obtained lower SEM marks tend to achieve final marks that are higher than their SEM marks. This finding indicates that once students receive feedback of their SEM results, the under-performing students place more effort into doing well in their exams. Hence their final marks tend to be somehow better than their performance in formative assessment. The observation confirms the useful role of formative assessment which is to inform the preparation of students in their learning towards mastery of the study subject [14]. In the converse, students that perform well during formative assessment tend to obtain lower final mark relative to the SEM mark. This trend may be attributed to lack of desperation on the part of students that perform well in formative assessments, lending relatively moderate effort in final examinations as compared to their counterparts with low semester marks.

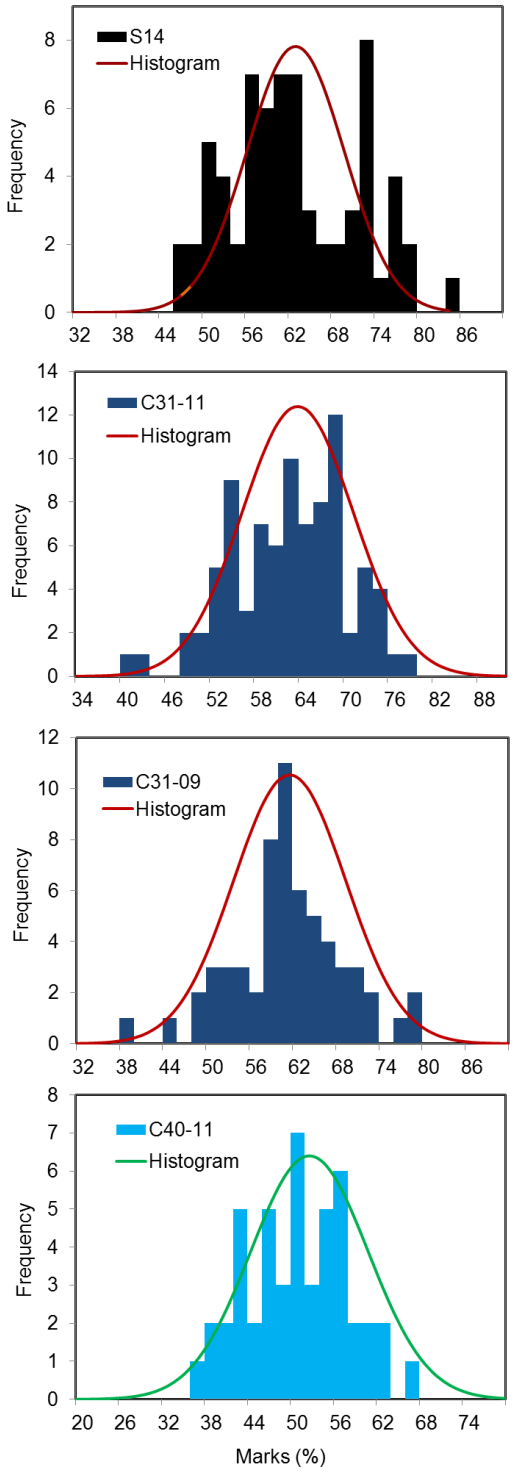

Fig. 1 Histogram of final mark results

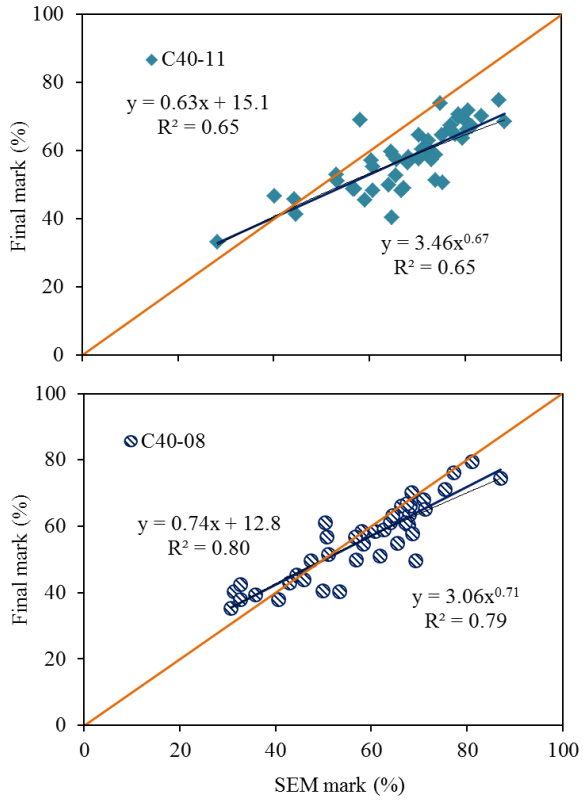

Fig. 2a Final marks versus semester marks for C40-11 and C40-08

V. CONCLUSION

A study was conducted to compare the relationship in academic performance of students in formative and summative assessments. Formative assessment marks are accumulated during the learning period through assignments, projects and class tests. Summative assessment consists of final examinations while final marks are awarded upon weighting of both semester marks and final examination marks. It was found that a strong relationship exists between semester marks and final marks attained by students. Accordingly, it may be possible to estimate the corresponding final marks using semester results.

Data shows that when the semester mark is low, the final marks achieved by students are higher as students improve their performance in final exams. But for students that obtained high semester marks, the final mark is generally lower than their semester mark. These results underscore the useful role played by formative assessments to improve the preparation of students towards subject mastery.

Further research is needed to determine models that may be applied towards potential use of formative assessments for summative purposes.

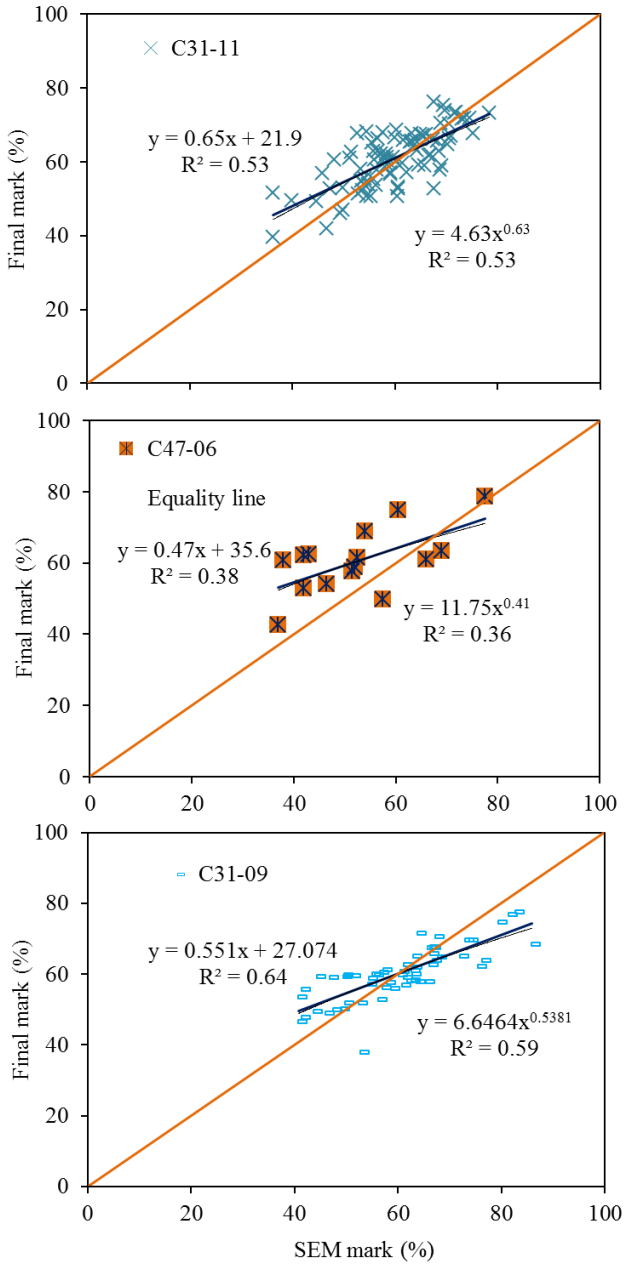

Fig. 2b Final marks versus semester marks for C31-11, C47-06 and C31-09

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Influence of Mode of Entry on Academic Performance of First Year Engineering Students in a Nigerian University

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Abstract
Data on academic performance and mode of entry of engineering students at University of Ilorin who had just completed the first year (100 Level) of their degree programme in 2014/2015 session were gathered and analyzed. There are two modes of entry into 100 Level Engineering programmes, namely: through Unified Tertiary Matriculation Examination (UTME) and through Remedial or Pre-degree programme. The conditions for a student to be in good standing academically at the end of 100 Level are: he or she must pass at least 9 credits out of 12 in Mathematics, 9 credits out of 12 in Physics, and 6 credits out of 10 in Chemistry; and in addition the student must have at least a Cumulative Grade Point Average of 2.00 out of a maximum of 5.00. Out of the 1,011 students who took the examinations in the 10 degree programmes, 57.2% of them were in good standing. Sixty-four percent of the 763 UTME candidates and thirty-seven percent of the 235 Remedial candidates admitted into 100 Level were in good standing. Out of the 433 students not in good standing, 427 of them had CGPA less than 2.00, 110, 131 and 41 of them did not pass the required number of credits in Mathematics, Physics and Chemistry, respectively. It was concluded that the UTME candidates were better than Remedial candidates. The Remedial programme in engineering should be sustained and the teaching of Physics should be improved upon in both the secondary schools and the Remedial programme.

Nomenclatures
Abbreviation

IGS	-	In Good Standing
NIGS	-	Not In Good Standing
UTME	-	Unified Tertiary Matriculation Examination
CGPA	-	Cumulative Grade Point Average
WAEC	-	West African Examination Council
BMAS	-	Benchmark Minimum Academic Standard
COREN	-	Council for the Regulation of Engineering in Nigeria
JAMB	-	Joint Admission and Matriculation Board
NECO	-	National Examination Council
NABTEB	-	National Business and Technical Examination Board

Introduction
Sound education for citizens is the bedrock and pillar of any buoyant economy. Jaja defined education as a mode of life and the process of education as the method of transmitting, advancing and consolidating culture [1]. Nations that have grown socio-economically have embraced qualitative education and devoted good chunk of their resources to training their citizens either formally or informally, while the results from nations that have starved their education sectors is evident. Furthermore, education is also contributory to the classification of countries in terms of development. For instance, developed countries have large proportions of their population educated while the reverse situation is the case in most developing countries. Generally, education is classified into formal and informal. Formal education starts from crèche and ends in higher institution. A major challenge for universities in developing countries is how to match the educational standard of world class universities in developed countries despite the poor infrastructural facilities,

socio-economic disadvantages and human resources deficiencies in these developing countries. Maintaining academic standard is particularly of great importance in higher institutions where damages and lapses from senior secondary schools cannot be hidden or ignored because they are evident in the performance of the students. To correct and restructure the educational systems in developing countries, efforts should be directed at enhancing the quality of training in elementary, junior and senior secondary schools.

There is increasing demand for spaces in Faculties of Engineering and Technology in Nigerian universities due to increasing turn out of applicants for admission into degree programmes from secondary schools. Presently, school certificate results at the level of 5 credits at one or two sittings from West African Examination Council (WAEC), National Examination Council (NECO) and National Business and Technical Examination Board (NABTEB) are acceptable as entry qualifications into Nigerian Universities for engineering programmes. The five credits must include Mathematics, Physics, Chemistry and English Language and the these four subjects are the subjects in which the Unified Tertiary Matriculation Examination (UTME) are written by the candidates.

There are two modes of entry into the first year (100 level) engineering programmes, namely;

(i) through Unified Tertiary Matriculation Examination (UTME) conducted by Joint Admission and Matriculation Board (JAMB); and

(ii) through one session Remedial programme, which is also known as Pre-degree programme.

Students who enter through UTME have at least 5 credits pass at one or two sittings in ordinary level or school certificate examination. They are expected to score reasonably high marks in the UTME and they are also subjected to post-UTME computer-based test in which they are expected to score above 60 or 70 % for most engineering degree programmes.

For students who enter through Remedial or Pre-degree programme, they may or may not have the five credits required at one or two sittings, they may also not have sufficiently high UTME score to be able to compete. It has been observed that for most students who enter engineering programme at University of Ilorin through Remedial programme, satisfying the O' level requirements of 5 credits at two sittings is not a problem, rather what they need to remedy is inability to score high marks in UTME.

In the first year, engineering students take courses in General Studies, Mathematics, Physics, Chemistry and Statistics. Tables 1 and 2 show the lists of courses taken by 100 level students in the Harmattan and Rain semesters.

Table 1: Harmattan Semester Courses for 100 Level

COURSE CODE	COURSE TITLE	COURSE STATUS	NO. OF CREDIT
CHM 101	General Physical Chemistry	Elective	3
CHM 115	General Practical Chemistry	Elective	2
GNS 111	Use of English I	Required	2
MAT 111	Elementary Set Theory and Numbers	Elective	3
MAT 113	Elementary Vectors Geometry and Mechanics	Elective	3
PHY 115	Mechanics and Properties of Matter I	Elective	2
PHY 125	Heat, Sound and Optics	Elective	3
PHY 191	Practical Physics I	Elective	1
STA 131	Introduction to Statistical Inference	Elective	2

Table 2: Rain Semester Courses for 100 Level

COURSE CODE	COURSE TITLE	COURSE STATUS	NO. OF CREDIT
CHM 112	General Physical Chemistry	Elective	2
CHM 116	General Practical Chemistry II	Elective	1
CHM 132	General Inorganic Chemistry	Elective	2

GNS 112	Use of English II	Required	2
MAT 112	Elementary Differential and Integral Calculus	Elective	3
MAT 114	Elementary Algebra and Trigonometry	Elective	3
PHY 142	Atomic and Nuclear Physics	Elective	2
PHY 152	Electricity and Magnetism I	Elective	3
PHY 192	Practical Physics II	Elective	1
STA 124	Introduction to Probability Distribution	Elective	2

To be allowed to proceed from first academic year to the second year of an engineering programme, the results of a student in the first and second semester examination are expected to satisfy the following conditions:

(a) At least nine credits out of twelve credits of mathematics courses must be passed;

(b) At least nine credits out of twelve credits of physics courses must be passed;

(c) At least six credits out of ten credits of chemistry courses must be passed; and

(d) The overall cumulative grade point average (CGPA) of the student should be greater than or equal to 2.00 out of a maximum of 5.00.

These conditions are in conformity with the standard stipulated in Benchmark Minimum Academic Standard (BMAS) produced by the Council for the Regulation of Engineering in Nigeria [2]. The course status shown in the third columns of tables 1 and 2 is very important. A student must pass the two courses labeled required before he or she can graduate. For the courses labeled elective, a student does not necessarily have to pass all of them before he or she can graduate. It is sufficient for a student to be in good standing at the end of 100 level to be allowed to graduate. Infact, it is only the result in the two courses designated as required that are used in computing the cumulative grade point average (CGPA) of the student for the purpose of classifying the degree at the point of graduation. None of these elective courses at 100 level is used for computing the CGPA at the point of graduation.

The aim of this work is to study the results of engineering students at the end of the first year to see which mode of entry produced a higher percentage of successful students and how the various criteria for being in good standing affected the students.

Methodology

Information on the modes of entry of students into 100 level and their results at the end of the first year of their study were obtained from the 10 departments in Faculty of Engineering and Technology of University of Ilorin.

Statistical analyses were done on the data using Microsoft Excel 2007 to obtain information on the number of students in good standing or not in good standing for each mode of entry and number of students not in good standing who failed to meet each of the four criteria for being in good standing.

Results

Table 3 shows for each department, the number of students who registered at 100 level and the distribution of these students among the UTME and Remedial modes of entry. The summary of the academic performance of the students at the end of the first year is shown in Table 4. Tables 5 and 6 show the breakdown of the academic performances of the students for UTME and remedial modes of entry respectively.

Table 3: The number of students who came in through UTME and Remedial modes of entry in the ten departments

DEPARTMENT	**REGISTERED STUDENTS**	**UTME CANDIDATES**	**REMEDIAL CANDIDATES**	**UNKNOWN MODE**
A	45	21	24	0
B	129	102	27	0
C	130	101	28	1
D	97	97	0	0
E	143	109	33	1
F	173	122	43	8
G	58	51	3	4
H	74	48	26	0
I	85	60	25	0
J	78	52	26	0

Table 4: Engineering students' performance after the first year

DEPARTMENT	**REGISTERED STUDENT**	**IGS**	**NIGS**
A	45	18	27
B	129	52	77
C	130	83	47
D	97	60	37
E	143	105	38
F	173	117	55
G	58	32	26
H	74	27	47
I	85	27	58
J	78	57	21

Table 5: Performance of UTME candidates

DEPARTMENT	**UTME CANDIDATES**	**UTME CANDIDATES IGS**	**UTME CANDIDATES NIGS**	**PERCENTAGE IGS**	**PERCENTAGE NIGS**
A	21	13	8	61.9	38.1
B	102	41	61	40.2	59.8
C	101	73	28	72.3	27.7
D	97	60	37	61.9	38.1
E	109	91	18	83.5	16.5
F	122	97	25	79.5	20.5
G	51	31	20	60.8	39.2
H	48	17	31	35.4	64.6
I	60	24	36	40.0	60.0

J	52	42	10	80.8	19.2

Table 6: Performance of REMEDIAL candidates

DEPARTMENT	REMEDIAL CANDIDATES	REMEDIAL CANDIDATES IGS	REMEDIAL CANDIDATES NGS	PERCENTAGE IGS	PERCENTAGE NIGS
A	24	5	19	20.8	79.2
B	27	11	16	40.7	59.3
C	28	10	18	35.7	64.3
D	0	0	0	0.0	0.0
E	33	14	19	42.4	57.6
F	43	18	25	41.9	58.1
G	3	1	2	33.3	66.7
H	26	10	16	38.5	61.5
I	25	3	22	12.0	88.0
J	26	15	11	57.7	42.3

Figures 1 and 2 show the comparisons of the percentages of students in good standing and those not in good standing respectively for the ten departments drawn from the data in Tables 5 and 6.

Figure 3 is a Venn diagram for students not in good standing showing how the four criteria for being in good standing affected the students.

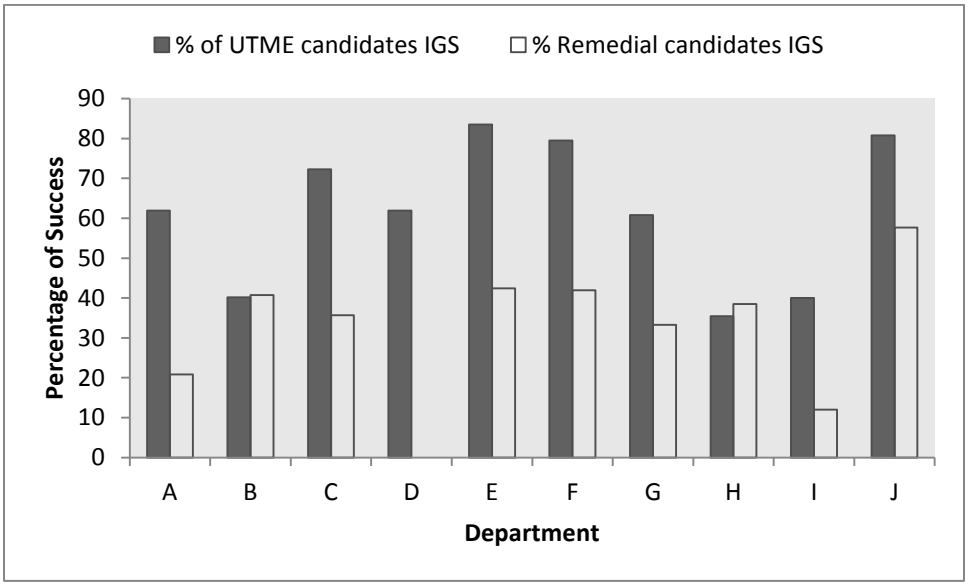

Figure 1: Percentages of students in good standing (IGS) for the two modes of entry in the ten departments

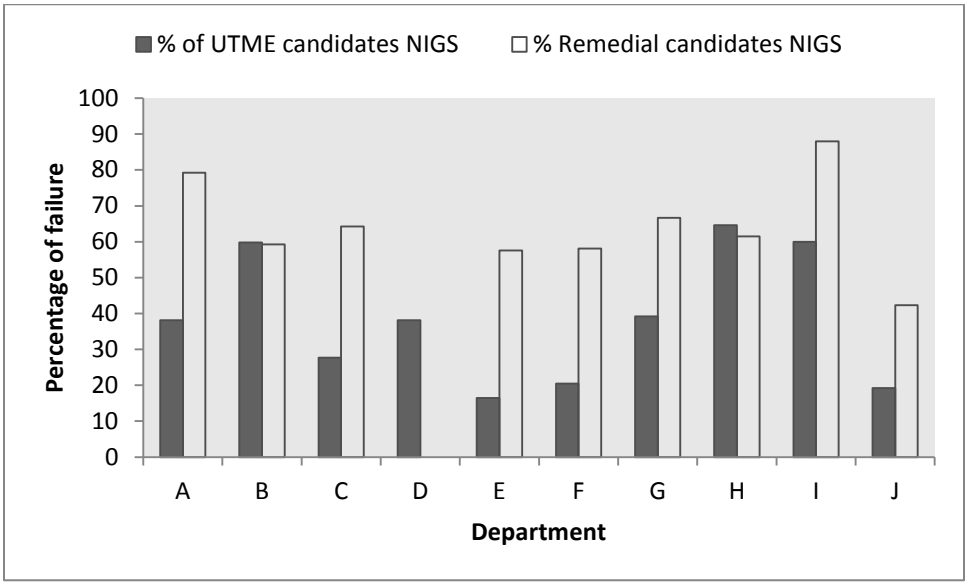

Figure 2: Percentages of students not in good standing (NIGS) for the two modes of entry in the ten departments

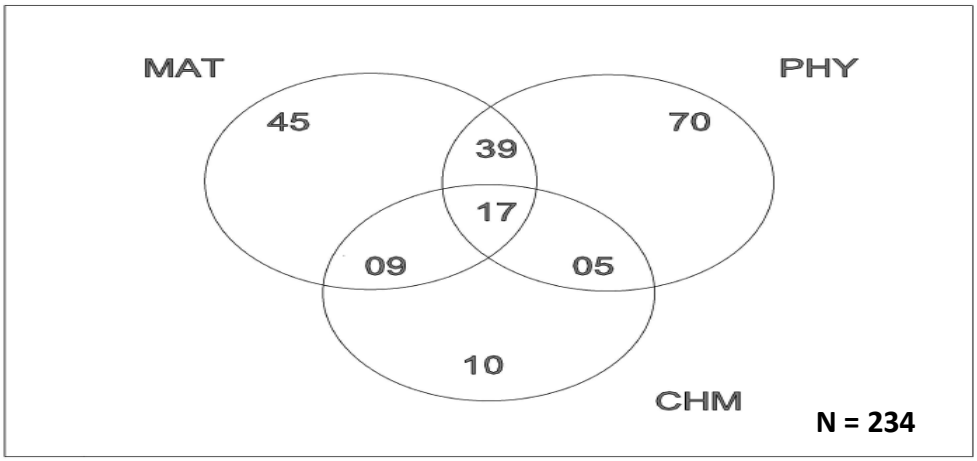

Figure 3: Venn diagram for students not in good standing for the two modes of entry in the ten departments

Discussion of Results

From Table 3, out of the 1,012 students admitted into 100 level in the ten engineering programmes, 75.4 % of them came in as UTME candidates and 23.2 % came in through Remedial programme. For the remaining 1.4 %, their mode of entry could not be determined due to incomplete records in their files.

The total number of students in good standing and those not in good standing in Table 4 add up to 1, 011 whereas the total number of students who registered were 1012. The difference was due to one student who got approval for suspension of studies. The percentages of students in good standing was 57.2 % while that for students not in good standing was 42.8 %.

From Tables 5 and 6, out of the 763 and 235 students that came in by UTME and Remedial modes of entry, 488 and 87 were in good standing respectively giving a success rate of 64.0 % and 37.0 % for UTME and Remedial modes of entry, respectively. The total number of those in good standing from Table 4 was 578 which exceeds the addition of those in good standing from the two modes of entry by 3. This can be

accounted for by the fourteen students whose modes of entry were unknown as shown in Table 3.

The students not in good standing were asked to withdraw from Faculty of Engineering and Technology. The attrition rates were 35 % and 63 % respectively for the UTME and Remedial modes of entry. The four criteria that must be met to be in good standing at the end of 100 level serves as a filter to drop weak students early and also help the Faculty to meet the stipulated students/teachers ratio for engineering programmes. It is important to note here that according to COREN BMAS, it is only the total student population in 200 – 500 levels that is used to compute student/teacher ratio for an engineering programme. Over the years since this filter has been applied, it has been observed that the incidence of students spending 7 years which is the maximum time allowed for their degree programme, and still not passing all the necessary courses, has been reduced to the barest minimum.

The Remedial programme has some merit in that it gives opportunity to some disadvantaged students to read engineering. At the end of 2014/2015 session, 87 of them met the condition for being in good standing (15 % of the total number in good standing). These students would not have been able to gain admission to read engineering because they could not score competitive marks in UTME and post-UTME screening.

From the Venn diagram in Figure 3, 110, 131 and 41 students failed to meet the conditions in mathematics, physics and chemistry, respectively. The total number of students whose CGPA were less than 2.0 were 427 students. Two hundred and thirty four students met the conditions in mathematics, physics and chemistry but could not meet the condition of having CGPA greater than or equal to 2.0. This means only 4 students has CGPA greater than or equal to 2.0 but had problem in meeting the condition in at least one of the three subjects. Out of the three subjects that must be satisfied to move to the second year in the Faculty of Engineering, the highest percentage of failure was recorded in physics. This is in agreement with the result obtained from a research on the attitude of students towards physics at a college of education in Nigeria [3].

Conclusions and Recommendations

From the results of the statistical analysis of the students who completed first year engineering programmes, it can be concluded that the students who came in by UTME mode of entry were better than those who came in by Remedial mode of entry.

The Remedial programme in engineering has merit and should be sustained since it gives opportunity to some disadvantaged students who would not have been able to compete well with others to come in, and moreover 37% of them in this case, passed at the end of 100 level. However, it is recommended that the number of students admitted into 100 level through remedial programme should not be more than 30% of the admission quota.

Since physics is the subject that had the highest number of students who failed, it is recommended that teaching of physics be improved upon in senior secondary schools and the Remedial programme.

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Engineering Education and Marketing of Engineering Business Enterprise: The Case of Construction Education

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Abstract **- The remarkably challenging features of the construction industry in the 21st century are globalization, the restructuring of the world economy, changes experienced in project financing and delivery systems, the pervasive utilization of information and communication technologies (ICT), and the increasing intensity of competition which threatens the growth, survival and profitability of engineering businesses with construction being the most affected. Marketing as a management function, which has been identified as imperative for businesses facing such challenges has not been welcomed by the construction industry. Marketing in construction is marked by misconceptions, misperceptions, lack of understanding among others which are traceable to education and training of construction management team members. This paper examines the aspects of construction education that impacts negatively on marketing performance of construction businesses, namely content and structure of curriculum for construction education, availability of construction marketing research reports and teacher qualification for teaching marketing to construction students. Finding reveal that the content of construction marketing syllabus is outdated and fall short of elements necessary for effective teaching the state of the art marketing in construction. Paucity of construction marketing research and lack of general helpful literature remains a challenge. Qualification of teachers appears to be a big challenge. Urgent need exist for revision of existing syllabus, efforts at addressing research towards addressing existing challenges with marketing in construction and guidelines for preparing teachers for teaching marketing to construction students. Construction education consultants, curriculum developers, construction education and training institutions and similar professional organization will find this useful.**

Keywords **- construction, education, marketing, marketing management, qualitative research.**

1. INTRODUCTION

Engineering education focuses predominantly on production of highly scientifically trained professionals from the universities with little or no management training particularly with marketing training [1], [2]. That philosophy underpinning engineering education and in particular construction education has existed for a number of factors such as these: the industry has never in the past met with difficulties in obtaining the required level of job to maintain survival and profit, the belief that their reputation and quality of their work will win them new orders, the focus on production as the most important part of the business and the attitude of looking for opportunities that fit their capabilities rather than adapting their capabilities to suit current and future market opportunities [3], [4], [5], [2]. These reasons may have been useful in the past, but that is flimsy and no longer tenable in the business environment today.

The operating environment of the construction industry has undergone considerable change in the last two decade. Many authors have identified the significant changes in the construction industry that threatens the construction business performance, survival and profitability in their operating environment. Such authors have also offered strategies and approaches that is basically effective marketing programme in dealing with such challenges. Notable amongst such authors is the statements by [6] that, *'Ever more demanding clients and fierce competition have resulted in many organizations having to look for ways of: differentiating themselves from their competition, focusing on customer service, getting to know their clients intimately, building lasting and trusting relationships with their supply chain and doing their marketing before trying to sell anything*' [6, pp. 1].

It is therefore not surprising that Naranjo [7] concur that *'Construction enterprises are aware of the importance of involving marketing in their management functions as a way to adapt themselves not only to the continuous changes in the industry, but also to satisfy their clients' demands, while being competitive and improving their business strategy*' [7, pp. 245). Yet, the industry is known to have a record of poor performance in most of the areas indicated above [5]. It is imperative for construction business enterprise managers and organizations to improve their business development strategies

and techniques [5], by embracing marketing management techniques in the management of their businesses in order to survive competition and be profitable.

Marketing is a management function that seeks to increase a target market, to build long-term relationships, to satisfy clients, to ensure the desired profitability [8], and to strengthen competitive advantage [9]. This is achieved through the "*matching of the organization's capabilities with the needs of customers in order to achieve the objectives of both parties-marketing"* [10, pp. 8). Marketing is also seen as "*...a social and managerial process by which individuals and groups obtain what they need and want through creating and exchanging products and value with others".* [11, pp. 6]. This makes marketing and business development closely inter-related although the two are distinct. Business development as a concept is considered as function of growing a business [12], which in this case is a construction business. Business development therefore includes marketing which also makes marketing imperative for business success [29].

Although marketing in the industrial and service sector is a well-known discipline, in the construction industry it is still misunderstood. This is reflected by the little scientific research and literature produced on this topic [2], [7]. This is attributable to construction education and training [1], [2]. The common theme that is running through available construction marketing literature is that the construction industry has performed poorly in marketing its products and services. Although, marketing has been established in manufacturing and many other service industries, in construction it is either been ignored or grossly misunderstood [2]. There exist many deeply held misconceptions or misperceptions or misunderstandings about the appropriateness and value of general management skills and marketing skills in particular [13], 14].

This has led to a situation that is best described as follows:
"The challenge of marketing to many professional service firms represents a large 'black box' filled with myths and half-truths, ambiguity in terms of the role of professionals and marketing, a dearth of information from both within and outside the profession, budget implications for the partnership and above all a surrounding background of uncertainty . Unable to face the uncertainty around the marketing 'black box' the responsibility is shifted from senior management of firm to individual partner, from marketing partner first to outside consultant and then to internal marketer who will further delegate many marketing tasks to subordinates and outside consultant." [15, pp. 21].

Pheng and Ming [16, pp. 273] supported this view saying that key professionals in the construction industry,

> "…have misinterpreted what marketing is all about. Some see it as manipulative, wasteful, intrusive and unprofessional, while most will see it as plain advertising and selling."

This is indicative of the stereotypical response of the construction industry to marketing issues. There was, and still is certain confusion over what marketing is all about and many firms have formed the opinion that marketing cannot be applied in their firms. It is against this background that this study was undertaken to examine some aspects of the teaching of marketing to construction management team members during their education and training. This paper identifies the factors contributing to the misunderstandings, misperceptions and/or lack of understanding about marketing in the construction industry.

Specifically, objectives of the study were:

1. To examine the structure and content of the existing marketing curriculum for construction education.
2. To examine availability of construction marketing research material that focus on challenges with marketing in construction.
3. To ascertain the qualification of teachers who teach the marketing for construction students.

2. METHODOLOGY

The observation by Morgan and Smircich [17, pp. 49] regarding research methodology is that the "…*appropriateness of a research approach derives from the nature of the social phenomena to be explored*". As noted by Hirshman [18], in marketing the key factors are socially constructed, like human beliefs, behaviours, perceptions and values. Based on this the research methods drawn for this study is the qualitative research paradigm which made use of interviews and/or observation. Similarly, [19, pp. 64) argues that, *"Interpretive qualitative research methods are valuable for in-depth understanding of phenomena in the marketing domain, in managerial and consumer contexts"*. In generating marketing information, market research agencies depend largely on qualitative methods such as observation and focus groups discussions. Accordingly, other authors for instance [20] report that in marketing research arena, interviewing and personal communication skills are considered more valuable than the

mastery of statistical techniques. The use of qualitative research is paradigm is therefore very much in vogue in marketing research.

From objectives of this study it can be seen that a qualitative research approach had to be adopted, as overwhelmingly the key factors to be studied are socially constructed, like human beliefs, behaviours, perceptions and values [18]. The study therefore adopted a telephone interview as a method to elicit information for the study. The interview was supplemented with observation and content analysis of available documents such as the Higher National Diploma (HND) in Building Technology syllabus.

2.1 Research design

2.1.1 Sampling

Adopting the purposive sampling technique, a total of ten interviewees were selected. One interviewee was selected from each of the ten polytechnics in Ghana. The criterion for the selection was a teacher who teaches 'marketing of construction product' course for building technology students in each of the ten polytechnics in Ghana. Interestingly, in each of the polytechnics, only one teacher was assigned such a course, either as an in-house staff or from a servicing department, mostly marketing department. Details of the background information about the respondents are shown in Table 1.

2.1.2 Interview

The study adopted the telephone approach which was considered the best option given the geographical spread of the ten polytechnics across each region of Ghana. The telephone interview approach saved time and resources that was not possible in the case of focus group discussion approach. Each interview lasted for about 30 minutes with a few exceptions.

In designing the questions for the interviews, repetitions were inserted to a certain extent, to avoid risk of slump errors. The questions were open ended, being neither negative nor positive nor with a value, in an attempt to not influence the interviewee with the researchers thoughts. To the greatest extent possible the questions were asked as similar as possible to all interviewees, create greater comparability. The questions were pre-tested on other people with positions that reminisce to the interviewees', to ensure that the questions can understood in the same way by all persons.

To enhance the credibility of this study, efforts were made to ensure accurate results are obtained. That included making sure all respondents were teachers who teach the subject marketing to construction students. This means the respondents have sufficient knowledge about the questions asked. Also, they were very much aware of the context of the study and they were prepared and willing to talk about the subject being studied.

During the interview, the same questions were asked to all respondents so that they are not influenced in different directions. In that case if different answers occur it will not be influenced by the way the interviewer acted. Notwithstanding that, different follow up questions were put forward if the interviewee does not answer as exhaustive as the previous respondents. This was done to ensure that all aspects of the study were adequately covered.

2.2 Analytical Procedures

All responses were transcript and analytical procedures that are particularly applicable to qualitative analysis as presented by [21] were used. These procedures are based on a deductive approach.

2.2.1 Pattern-Matching

This involves predicting a pattern of outcomes based on theoretical propositions to explain what is expected to find. The basis of the procedure is the theoretical construct or framework, which will dictate the relationships between variables.

2.2.2 Explanation Building

Explanation building involves building an explanation while collecting data and analyzing them. This method seems to be similar to the grounded theory approach. Both pattern-matching and explanation building analytical procedures seem suitable for the present research and have been given due consideration in the process of data analysis and discussion

2.2.3 Qualitative Analysis Approach

The approach used in this study follows the approach by [22] qualitative analysis. Based on their suggested approach, the mass of qualitative data was disaggregated into "meaningful and related parts or *categories*" (p.382). The essence was to allow for a rearrangement of data and to enhance a systematic analysis. The approach transformed the data and made it suitable for:

- Better comprehension and data management
- Merging of data from different transcripts and related notes
- Identifying key themes or patterns for further analysis

- ❖ Development or testing of hypotheses or theories based on these
- ❖ patterns or relationships
- ❖ rawing and verifying conclusions

Source [22]

The analysis of data was done on all of the ten respondents' transcripts. Each topic or theme from that list became a general category of analysis. It is important to mention that certain categories had to be kept general, as there has been a certain variation in the amount and level of detail of the data. The practical approach of data analysis involved the reading line by line of the transcripts and allocating the relevant information from the line(s) or paragraph(s), depending on their meaning and suitability, into one of the defined categories. The written analysis of this process has followed the search for emergent patterns and relationships in the re-arranged data grouped into the identified categories.

3 ANALYSIS AND DISCUSSIONS

Table 1, presents the details of the background information about the interviewees. Upon analysis, a trend emerged that shows inherent challenges to teaching of marketing to construction students.

Table 1: Background of interviewees

Background	Number of occurrence (%)
Education and Training of Teacher	
▪ Construction related	9 (90%)
▪ Non-construction related	1 (10)
Teaching experience	
▪ Less than 10 years	2 (20%)
▪ 10years and more	8 (80%)

Table 1: Background of interviewees – Cont.

Research Interest/Area/specialization/publication	
▪ Marketing related	1 (10)
▪ Non-marketing related	9 (90)
Publications (conference and Journals)	
▪ Marketing related	1 (10%)
▪ Non-marketing related	9 (90%)
Affiliation with marketing related professional body	
▪ Marketing related eg. CIM	0 (0%)
▪ Non-marketing related	10 (100%)

Source: Author's construct

From Table 1, out of the ten interviewees who teach "marketing of construction product", all except 10% has masters' degree in non-construction related discipline. That is actually due to the fact that the teacher is not an in-house staff of the Building Technology department; rather he is a servicing lecturer from the department of marketing studies. The remaining 90% are in-house staff with masters' degree (Master of Science and Master of Philosophy in various fields of construction with the majority in Construction Management, Building Technology and Construction Procurement management. Judging from the nature of education and training of such programmes [1], the likelihood is that the nine teachers may not have an in-depth knowledge about marketing. This can greatly affect their delivery of the subject to the understanding of the students.

Regarding the experience (in terms of years of teaching the subject) of interviewees, only 20% have taught the subject for less than 10 years. Since majority (80%) of interviewees has more than 10years experience in teaching the subject, it is expected that such teachers will exhibit their marketing skills by their research interests and marketing related publications they have to their credit. A vast majority of interviewees (90%) do not see marketing as a subject of interest to them or as their area of specialization (see Table 1). Correspondingly, Majority (90%) of interviewees do not have any construction marketing related publication to their credit, be it conference paper of journal article (see Table 1). This comes as no surprise because of their lack of interest in the subject and the result is no research work in the subject the can result in publications. These teachers have many publications in other construction management disciplines such as estimating, scheduling, cost control, safety, maintenance among many others. It is just that the lack of interest does not stimulate any research in the area of marketing which can result in some publications.

3.1 Content and structure of construction marketing syllabus

It is difficult to define the "product" in the construction industry; and it is even more difficult to define its marketing [6]. Yet such combination of words is used to make the phrase "Marketing of construction product" which is the name for the only marketing course in the construction curriculum for training Higher National Diploma (HND) graduates in Ghanaian Polytechnics. From the onset, confusion about

marketing starts in the mind of the students, which may never be erased since there exist no state of the art marketing course content. It can be concluded therefore that the construction industry's professionals are being educated without a systematic study of this important aspect of management. In a similar vein, It has been noted by [1], that professional education and training have always been streamlined and narrowed down to the production of highly trained professionals from the universities with little or no management training.

A close examination of the content of the construction marketing course reveals a complete lack of the elements necessary for effective training that can result in acquisition of relevant marketing knowledge and skills. The key element includes: an aim which lack purpose and focus. The syllabus aims at 'developing in the student, a comprehensive understanding of the marketing techniques used in the built environments products' with a detailed course outline which includes: Nature and practice of marketing of construction products; Commercial; housing and industrial buildings. Study of marketing strategy and factors such as consumer behavior, together with Policies and techniques and their application to the selling problems of construction enterprises are also included [28], (see Table 2).

Table 2: Aim and Course Content of 'Marketing of Construction Product' course for HND Building Technology Programme.

The main aim of this syllabus is to develop in the student, a comprehensive understanding of the marketing techniques used in the built environments' products. Topics should be considered in the context of current and best professional practice. ***Detailed Course outline includes:*** Nature and practice of marketing of construction products; Commercial; housing and industrial buildings, study of marketing strategy and factors such as consumer behaviour. Policies and techniques and their application to the selling problems of a construction enterprises.

Source: [28]

These topics certainly fall short of what is required for effective training in marketing especially in the construction industry where the intensity of competition arising out of changes in the industry threatens survival of business enterprises operating in such environments. It lacks clear purpose, focus and elements that can impart requisite skills to learners to enhance their marketing management skills. Comparing this content to marketing management function in a business enterprise reveals its weaknesses.

Marketing management function in a business enterprise involves the practical application of marketing techniques and the management of a firm's marketing resources and activities [23]. The application of marketing techniques and the management of firms' resources involves four main step which are; (1) understanding the marketplace and customer needs and wants, (2) designing a customer-driven marketing strategy, (3) constructing a marketing program that delivers superior value and building profitable relationships, creating customer delight, and (4) capturing value from customers to create profits and customer equity [24]. Details of what is involved in each step are given in Table 2.

Table 3: Steps in marketing management process

Step	**Marketing Management Process**	**Key Elements involved**	**Ref.**
1.	Understanding the marketplace and customer needs and wants	marketing research and analysis, analysis of business opportunities in the market, collecting information about potential customers, competitors and the marketing environment, analyzing the company's strengths and weaknesses	[25], [26], [27]
2.	Designing a customer-driven marketing strategy	company divides the market into major segments, selects the target market that the company can best serve, development of differentiating and positioning strategy for the target market	[25]
3.	Constructing a marketing program that delivers superior value and building profitable relationships, creating customer delight, and	A marketing program should include decisions on marketing resources necessary to achieve marketing objectives and marketing techniques to be used to pursue marketing objectives in the target market. This stage focuses on how to best implement the chosen strategy	[25]
4	Capturing value from customers to create profits	Measure progress against marketing objectives in order to ensure that the implementation of marketing programs achieves the desired	[23], [24],

	and customer equity	marketing objectives in a cost-efficient manner A variety of metrics, such as customer metrics (e.g., customer loyalty/satisfaction, brand image, etc.), market metrics (e.g., market share, sales volume, etc.), financial metrics (e.g., sales value, profits, etc.), etc., can be used to measure marketing performance	[25]

Source: Author's construct based on [23], [24], [25], [26], [27]

These four processes in the marketing process (Table 3) is expected to form the basis of any course on marketing that is designed to equip learners with relevant knowledge and skills necessary for marketing a business enterprise. It is therefore important that the construction marketing course must reflect some topics relevant to achieving such objectives.
However, with regards to the structure of the syllabus for construction marketing education, no specific structure relevant for understanding marketing management processes in an organization is identified. This is expected because the content itself is irrelevant to understanding marketing.

3.2 Construction marketing research

The low priority given to marketing in construction is reflected in the paucity of reported research and helpful general literature [2]. This condition has been blamed on construction education and training mainly in the past and that has been vindicated today. In a study by [2], comparison of literature on construction marketing to other construction management functions such as estimating, scheduling and cost control revealed that construction marketing literature is very sparse. Such literatures according to [7] are also intermittent their nature of occurrence.

Figure 1, gives the picture of development of marketing research in construction from 1970 until 2009. It indicates that no research interest on this subject existed before 1970. After that year some interest has been shown, but that was not strong until 1995, the number of papers ceased to be very few and intermittent. After this year, interest at research on this subject has gone up significantly: 50 % of the papers were published in the last decade (Figure 1).

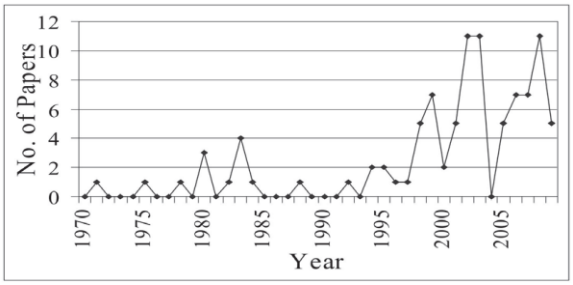

Figure 1: Developments in construction marketing research
Adopted from [7]

It is noteworthy, however, that the focus of reported research does not seem to address the central fundamental problem: lack of understanding of what marketing is. This is a human factor yet construction marketing research that focus on human factors are among the least researched areas in construction marketing [7]. Details are shown in figure 2.

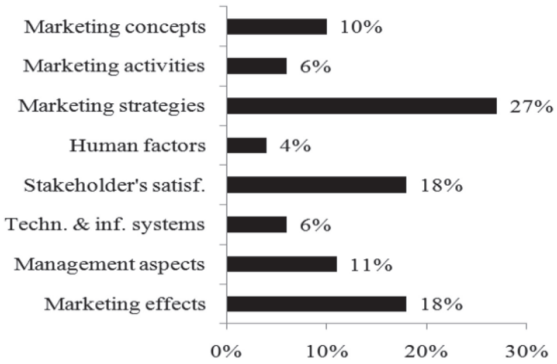

Figure 2: Marketing aspects researched
Adopted from [7]

Recent research works are also taking different dimensions. They seem to focus on models for selecting marketing activities to optimize the cost effectiveness of the marketing process [25]. Such focus still fails to address the fundamental problem. The need for more research works that focus on the challenges with marketing in construction will provide adequate, relevant and industry specific training resources for education purposes. Such literatures are necessary in dealing with paucity or sparse nature of construction marketing literature but also the human resource deficiencies in marketing of construction businesses.

3.3 Qualification of teachers

By default the education and training of construction management team's members does not place any much emphasis on the marketing which results in lack of understanding of the true meaning of marketing. To the construction student, marketing is an alien concept that is new to them and is even viewed with skepticism. It takes a teacher who is qualified in terms of having some professional qualification in marketing to dispel the erroneous impression about marketing. However, the teachers have gone through the same education that fails to place any importance to marketing.

There is even a greater challenge when someone with professional qualification is brought in because he also lacks knowledge about the dynamics of the construction industry. It is assumed that servicing staff from the marketing department may be an ideal person to teach the subject because, as marketing professional with masters in Business Administration and majored in marketing (MBA Marketing),

he has received professional training in marketing. Although having professional qualification in marketing may be considered as having marketing skills, this may not be enough because such professionals lack the domain specific knowledge about the construction industry and the dynamics involved in marketing it.

Lack of awareness of the unique characteristics of the construction industry, recent development and changes occurring in procurement practices, project financing and delivery systems can be a great limitation for his delivery. Again, the construction industry has peculiar characteristics that make it different from other industries such professionals might have been exposed to. Construction is capital intensive, weather, and location dependent, involves one-time unique purchase, and is characterized by a long procurement process [9]. Construction is complex and entails extensive planning and involves a multidisciplinary team. Such is not the situation in many industries that the MBA marketing professional may have been exposed to during the period of his training.

4 CONCLUSIONS AND IMPLICATIONS

4.1 Conclusions

Construction enterprises are aware of the importance of implementing marketing in their management functions as a way to adapt themselves not only to the continuous changes in the industry, but also to satisfy their clients' demands, while being competitive and improving their business strategy. Despite this knowledge marketing is at best adopted with skepticism and at worst not practiced at all. This paper has examined the root cause this problem.

Existing content and structure of marketing course for construction education is obsolete and do not reflect the current state of the art marketing relevant for use in the construction industry. Again, the structure is deficient or do not capture the core element of the four main steps in marketing management process, which are; (1) understanding the marketplace and customer needs and wants, (2) designing a customer-driven marketing strategy, (3) constructing a marketing program that delivers superior value and building profitable relationships, creating customer delight, and (4) capturing value from customers to create profits and customer equity. Whilst these key elements are nonexistent, other construction management functions such as estimating, scheduling and cost control are heavily present. This attests to the low priority that is given to marketing in the construction education.

Paucity of literature on construction marketing exists. The few existing literature are also sparse. This has resulted in general lack of research reports and helpful general literature on construction marketing. The focus of the existing few literature do not address the fundamental problem of marketing in construction which is the lack understanding, misperceptions and misunderstandings of marketing in the construction industry. Marketing is grossly misunderstood in the construction industry. There exist many deeply held misconceptions or misperceptions or misunderstandings about the appropriateness and value of general management skills and marketing skills in particular.

Many of the teachers seem not ideal to teach the subject. Many of the teachers have gone through the same education and training that does not place any importance on marketing. Again, marketing professionals from academics departments or industry may also lack construction industry specific knowledge which can enhance their effectiveness in imparting knowledge to construction students so as to improve their marketing skills and knowledge.

4.2 Implications

As noted in a recent study, *'Construction enterprises are aware of the importance of involving marketing in their management functions as a way to adapt themselves not only to the continuous changes in the industry, but also to satisfy their clients' demands, while being competitive and improving their business strategy*' [7, pp. 245]. To improve the application of marketing in construction, management team members must understand what marketing is and the processes of its implementation in the management of a business enterprise.

The result of this study suggests that the marketing curriculum for construction education lacks the state-of-the-art marketing content and structure required for modern day understanding of the subject and its application in business organizations. National Accreditation Board (NAB), National Board for Professional and Technical Examination (NABPTEX) and educational curriculum development consultants must work hard to review the construction marketing curriculum to reflect current developments in the subject of marketing in terms of content and structure.

The findings also indicates the paucity of literature on construction marketing and the sparse nature of occurrence of the existing few research works. The absence of relevant training materials does not auger well with effective training. Construction management researchers must refocus some attention to marketing in construction. This will improve the availability of literature on the subject to improve teaching and learning.

Finally, the impact of teacher variables also in the teaching of marketing is critical to understanding by students. Lecturers from marketing department are not recommended because they do not possess construction industry specific knowledge. Notwithstanding that, teachers who are in-house staff but not construction marketing researchers need some marketing training to prepare them for the task. This can take the form of seminars, workshops and other professional training in marketing. In the a

4.3 Limitations and Directions for future research

Some limitations might be related to collecting the data and interpreting the results. The remarkable one may be omission of important variables. For instance, additional factors that can also affect understanding of marketing to construction students, such as duration of the marketing course can be added as additional factors that affect marketing in construction.

Future research must focus on the following issues: impact of construction marketing education on marketing intention of construction management team members, effect of duration of construction marketing education programme on marketing intention on construction students, stability of marketing intention, marketing intention and actual behavior of construction management team members.

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Mentoring On Retention of Graduate Employees in the Construction Sector: A Literature Review

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***Abstract* - The business world has long known and relied upon mentoring as a proven technique for developing in house talent, mentoring is experiencing resurgence because business leaders not only recognize the benefits of transferring knowledge among employees. Although mentoring theory, research and practice have begun to mature, relatively few articles on mentoring of graduate employees, retention have appeared in the human resource development literature. The aim of this article is to look at the experiences, challenges and problems contributing to retention of graduate employees within construction companies. Examine practices on mentoring through the lens of (HRD), within the construction industry, and furthermore the study describes better practices that organizations can use to address the threat of lost knowledge caused by changing workforce demographics. The study adopted a literature review method of data collection, with a special focus on mentoring, retention, human resource management. The data used in the report was mainly qualitative, based on the content analysis, and historical data. The study also, indicated knowledge transfer assists employees in improving their skill sets which increases their marketability. The early success of the initiatives described provide useful lessons for the construction industry and executives who recognize that knowledge retention and mentoring of employees are critical for sustaining future organizational performance.**

***Keywords* - retention, mentoring, graduates employees, human resource management.**

I. INTRODUCTION

Mentoring is considered to be the oldest form of knowledge transfer [1] .For centuries, in agrarian and hunting societies, one was surrounded by many adults who served as occupational role models, i.e., mentors, and the knowledge that was passed down from these mentors benefited both the individual and the collective organization of which one was a part [2]. The historic transition to a knowledge society [3] concurrent with the rapid development of new technologies means that organizational success is dependent upon knowledge workers [4,3]. The transfer of knowledge and the retention of key knowledge workers, thus, is critical to organizational competitiveness [4, 5, and 6]. This requires organizations and researchers to focus more closely on processes such as mentoring that can support effective knowledge transfer and retention of critical knowledge workers. Organizations that rely upon effective knowledge transfer to sustain a competitive advantage face a dilemma. If such organizations do not have processes to promote effective knowledge transfer, productivity will suffer and organizational survival may be threatened [7]. Conversely, if organizations do invest in knowledge transfer they risk increasing the marketability and job mobility of their employees which could potentially harm retention [8]. Job mobility has increased in past decades because similarities in processes and technology mean that knowledge is less idiosyncratic to a particular organization and thus is more transferable [8].

The role of mentoring in fostering the development of employees is discussed as a component of a number of employee development theories and is noted to be an important means of facilitating learning in our society and in organizations. It is not surprising that mentoring has been recommended as an essential tool for human resource development. The recent publication of several reviews of research on mentoring [9] highlight that our knowledge of mentoring is maturing. Noteworthy advances have been made in understanding the nature, process, and outcomes of mentoring relationships. However, the literature on mentoring is still fairly young [10, 9] many questions about mentoring remain poorly answered or have yet to be thoroughly investigated, within the construction industry.

Employee retention is becoming a major issue with most employers. Many organizations have not kept up with the changing needs of the workforce causing many good people to leave. Combined with the growing worker shortage, they are unable to fill jobs with qualified people. Employee retention is most critical issue facing corporate leaders as a result of the shortage of skilled labor, economic growth and employee turnover. Organizations today face a dilemma regarding the retention of key knowledge workers. Knowledge transfer amongst employees is crucial for organizational productivity. Turnover is a critical human resource issue in all sectors of the economy. Turnover affects productivity, product and service quality, and profitability.

The cost of replacing workers is high, finding skilled employees can be difficult, and investments in training are less secure. Unexpected workforce attrition may place employers at a serious disadvantage. And this turnover could occur when slimmed-down companies have little redundancy in job roles, exposing them to greater risk of losing important organizational knowledge. To minimize the impact of workforce turnover, companies need a proactive strategy for knowledge retention and transfer. Regardless of economic conditions, employee turnover happens. The financial impact of workforce mobility is well documented. The Society for Human Resource Management found that direct replacement costs can reach as high as 50% to 60% of an employee's annual salary. The total costs of replacement, including training and the loss of productivity, can range from 90% to 200% of an employee's annual salary [11].

II. PURPOSE OF THE STUDY

A significant percentage of the employees, within the construction sector is nearing retirement age over the next ten years. These employees have acquired a tremendous amount of knowledge about how things work, how to get things done and who to go to when problems arise. Losing their expertise

and experience could considerably reduce efficiency, resulting in costly mistakes, unexpected quality problems, or significant interruptions in services and/or performance. In addition, faster turnover among younger graduate employees and more competitive recruiting and compensation packages add significantly to the mounting concern about the organization's ability to sustain acceptable levels of performance. Mentoring is an interesting addition to the (Human Resource Development) literature because many of the characteristics of an organization's, traditional approaches to employee human resources can't be easily changed. For instance, turnover, retention of graduate employees and the selection of processes may be able to slowly change the employee landscape, but they can't change a crucial element of human resources within organizations, the individual employees' characteristics. The study will contribute to knowledge by coming with recent information which can assist construction companies in understanding the problem of not retaining staff and its cost implications.

III. OBJECTIVES OF STUDY

- To determine current retention strategies
- To describe better practices that organizations can use to address the threat of lost knowledge
- To evaluate the impact of mentoring on retention of graduate employees within organizations.

IV. LITERATURE REVIEW

Mentoring as a form of strategic human resource management is an interesting addition to the HRD literature because it provides a mechanism of change for individual employees, within construction organizations. Having a powerful human resource development (HRD) organization is a worthwhile asset of companies, and an enterprise's efficiency is closely connected to human capital's managerial and developmental systems [12]. Human capital plays an important role in the success of an organization. Employees with high skills and expertise increase their chances of being at the workplace. Thus, successful construction companies and/or organizations will be those that are able to engage, educate, develop and retain highly skilled employees. In order to do so, developing a learning environment within organizations is, therefore important to the future of HRD.

The number one issue for South Africa and across the Globe is people- finding good, strong people with the right education and training, and being able to retain them. The shortfall in talent has global impact, there is a high rate for competition for staff around the world, getting the key people is a big issue. The challenge for employers then lies in being recruit the top choice of top talent, if they want their businesses to thrive and maintain competitive advantage, positioning your employer brand to be the top choice of top talent, has become a critical business task, the cost of talent attrition is on the increase as the employers realize it is about much more than recruitment costs. The retention of key employees within construction companies is probably the biggest challenge in human capital management today. One of the key features in the new world of work is the increasing mobility of knowledge workers. Company leaders around the world have for years been speaking about future skills shortages. This critical need applies to all disciplines such as construction, business management, agriculture, politics, science, information technology, medicine and so forth. The challenge for business owners and leaders is to identify, attract and retain talent in their companies. The challenge for talent itself is to direct and apply its value to the market appropriately, and the challenge for the world is to place talent into the right leadership roles to guide nations towards positive interactions and the development of our future prosperity and survival. The world requires experienced and knowledgeable leaders and the challenge is on for organizations to compete in this new global talent marketplace. A number of researchers have studied how gender and race affect mentoring, within organizations. From the protégé's perspective, key questions that have been investigated include (1) are women (or minorities) less likely than men (or Caucasians) to have a mentor? (2) Do women (or minorities) receive the same kind and amount of mentoring functions as others? And (3) do women (or minorities) gain the same favorable outcomes from mentoring as men (or Caucasians) [9] .The majority of research suggests that women and minorities are as likely as men and Caucasians to have mentors, but inconsistent findings make it difficult to draw definitive conclusions about relationships between protégés' gender or race and mentoring functions [9].

Mentoring programs in organizations can be helpful in improving performance and transferring knowledge, and lead to higher job satisfaction and retention of employees, resulting in higher business productivity. In the workplace, relationships naturally develop between co-workers, clients, supervisors, and subordinates. One type of relationship that can be very beneficial in the workplace, even advancing an individual's career, is the mentoring relationship. The mentoring relationship between a mentor - a more experienced employee - and mentee can provide both parties benefits offering support and knowledge in performing a job, increased admiration in the office, and navigating the politics of an organization. The benefits usually relate to an increase in performance. This relationship, although usually positive, is not without some pitfalls and risks. A mentoring relationship can sometimes develop into a negative situation with a mentor possibly sabotaging a mentee or not providing the necessary career support [13].

V. THE IMPORTANCE OF KNOWLEDGE TRANSFER AND WORKER RETENTION

When a business loses employees, it loses skills, experience and "corporate memory". The magnitude and nature of these losses is a critical management issue, affecting productivity, profitability, and product and service quality. For employees, high turnover can negatively affect employment relationships, morale and workplace safety. The cost of replacing workers can be high, the problems associated with finding and training new employees can be considerable, and the specific workplace-acquired skills and knowledge people walk away with can take years to replace. The problem of turnover can be addressed through a variety of pro-active retention strategies: workplace policies and practices which increase employee commitment and loyalty. Knowledge transfer initiatives on the other hand, ensure that the knowledge and expertise of a company's employees its 'corporate memory'—are systematically and effectively shared among employees. They can offset the negative impact of turnover, but can also work pro-actively to reduce turnover by providing learning and skills development opportunities to employees - factors known to reduce turnover.

Employee retention and knowledge transfer are two elements of a more general concern that might be best termed 'skills management,'—i.e., everything that has to do with recruiting, maintaining and developing *the necessary mix and levels of skill required* to achieve organizational and business objectives [14].

VI. BEST PRACTICES IN RETENTION AND KNOWLEDGE TRANSFER

In order to address the threat of lost knowledge caused by changing workforce demographics. The heart of any knowledge-retention strategy is its knowledge- sharing practices. There are many sorts of methods that contribute to knowledge capture, sharing and re-application: after-action reviews, communities of practice, face-to-face meetings, mentoring programs, expert referral services, training, video conferencing, interviews, written reports, etc. While many of these practices are helpful for creating a general knowledge-sharing environment, the question remains which ones are most useful for addressing knowledge-retention problems?

Based on the review of the literature, the list of retention practices that captures the main types of interventions discussed in the HR literature includes [14]:

Competitive and Fair Compensation is a fundamental starting point in most strategies to attract and retain employees. However, there is general agreement that compensation levels do not single-handedly guarantee employee retention. Common best practices include the use of industry surveys to benchmark and position wage and salary structures to be fair and competitive.

Adequate and Flexible Benefits can demonstrate to employees that a company is supportive and fair, and there is evidence to suggest that benefits are at the top of the list of reasons why employees choose to stay with their employer or to join the company in the first place. Many companies are responding to the increasingly diverse needs of their employees by introducing a greater element of choice in the range of benefits from which their workers can choose. Flexibility in benefits packages can enhance retention, as it creates responsiveness to the specific needs and circumstances of individual employees.

Training, Professional Development, and Career Planning are effective ways to enhance employee retention. Training constitutes a visible investment that the company makes in the worker, providing him or her with new skills, and greater competencies and confidence. Training often leads to work that is more intrinsically rewarding. Combined with effective communication about how an employee's efforts at developing skills will lead him or her to more challenging and meaningful positions *within* the company, training encourages workers to make longer term commitments to their workplace: it permits them to see a future with the company. *All* of the companies we interviewed were very active in the area of skills training and professional development. Many have put in place effective internal promotion programs that allow even their unskilled and semi-skilled workforce to move towards positions of greater responsibility and remuneration within the company.

Knowledge Transfer – cross-training, coaching and mentoring, phased in retirement.

While employee retention practices seek to retain *workers*, knowledge transfer practices seek to retain *skills*, through both formal and informal exercises in information sharing and the building of collective knowledge. Mentoring and coaching, phased-in retirements, and cross-training and job rotation, are types of knowledge transfer that overlap with training. Knowledge transfer also includes the use of technology-based tools—databases, intranets, groupware—aimed to support knowledge sharing among individuals, and to permanently document and keep knowledge that is vital to business performance.

VII. CURRENT RETENTION STRATEGIES

The turnover of key employees can have a disproportionate impact on the business and the people organizations wish to retain are probably the ones most likely to leave [15]. Every worker is five minutes away from walking out of the door to a better offer. There is no such thing as a job for life and today's workers have few qualms about leaving employers for greener pastures, the average permanent job in the UK lasts six years. Concerted action is required to retain talented people, but there are limits to what any organization can do. It is also necessary to encourage the greatest contribution from existing talent and to value them accordingly. Retention strategies should be based on an understanding of the factors that affect them. For early career employees (30 years and under) career advancement is significant. For mid-career employees (age 31 -50) the ability to manage their careers and satisfaction from their work are important. Late career employees (over 50) will be interested in security. It is also the case that a younger workforce will change jobs and employers more often than an older workforce, and workforces with a lot of part timers are less stable than those with predominately full- time staff.

The specific factors that affect retention are:

Company image;

- Recruitment, selection and deployment;
- Leadership- employees join companies and leave managers;
- Learning opportunities
- Performance recognition and rewards.

A study that was conducted in regard to high flyers, found that the factors that aided the retention and motivation of high performance included providing challenge and achievement opportunities (for example assignments), mentors, realistic self-assessment and feedback processes.

VIII. BASIS OF THE STRATEGY

A retention strategy takes into account the particular retention issues the organization is facing and sets out ways in which these issues can be dealt with. This may mean accepting the reality, that the market, not the company will ultimately determine the movement of employees, it can be difficult to counter the pull of the market- you can't shield your people from attractive opportunities and aggressive recruiters [16]. The old goal of HR management to minimize overall employee turnover- needs to be replaced by a new goal, to influence who leaves and when. This as proposed could be based on risk analysis to quantify the seriousness of losing key people, or of key posts becoming vacant [17].The overall strategy of most companies is to become an employer of choice. The recruitment of key individuals who will contribute significantly to the value- creating capacity of the firm is crucial to success. The aims are to establish the brand image of the organization- how others perceive it (employee branding), to become an employer of choice, and to target recruitment and selection to obtain the sort of people the

organization needs [18]. Employer branding is the creation of a brand image of the organization for prospective employees. It will be influenced by the reputation of the organization as a business or provider of service as well as its reputation as an employer. Employer branding is a concept of applying to the recruitment process the same marketing coherence used in the management of customers [15]. The approaches required to develop an employer brand are:

- Analyse what ideal candidates need and want and take this into account in deciding what should be offered and how it should be offered;
- Establish how far the core values of the organization support the creation of an attractive brand and ensure that these are incorporated in the presentation of the brand as long as they are values in use (lived by members of the organization) rather than simply espoused;
- Benchmark the approaches of other organizations (the Sunday times list of the 100 best companies to work for is useful) to obtain ideas about what can be done to enhance the brand;
- Be honest and realistic.

Sign bonuses may disappear due to market volatility. In 2015 almost every senior management professional placed in the financial services sector received a sign on bonus. And hand in hand with that came a significant increase in recruitment expenditure that year. Figures show that certain candidates received sign on bonuses from between 30% and 100% of their annual package [19]. However, it must be remembered that sign on bonuses are often paid in lieu of a forfeited bonus that a candidate would lose when leaving their current job to join a new organization. It can also be used to compensate candidates for the loss of share options. In the past, it was certainly not

Taken as a given that top professionals would be offered a sign on bonus as an incentive to accept a job offer. However, in late 2006 we began to see the increasing use of joining bonuses as construction companies began to feel the pressure of skills shortages in certain sectors. This approach became an imperative part of the negotiation process as candidates were unwilling to walk away from hard earned bonuses or share options, no matter how enticing the role or basic offer.

In 2015, the asset management, investment banking and stock broking sectors had good returns and many employees stood to receive substantial bonuses because of this. Companies seeking the right talent had to factor this into their offers in order to secure the right skills [20]. In addition to compensating for lost income, some construction companies would sometimes pay a pure sign on bonus, or a welcome to the company bonus. Although it is rare, when a candidate's expertise can make a significant contribution to the bottom line, a happy hello is sometimes deemed worthy of the financial layout. This year (2016), however, with economic instability and market volatility, it remains to be seen whether companies' pockets will be so deep. There has been some concern that an expectation has been created amongst highly skilled individuals that a sign on bonus is now the norm, but people should be realistic about market conditions and give full consideration to the bigger picture of the career opportunity, before contemplating making a move to another organization.

IX. THE IMPACT OF MENTORING ON RETENTION OF EMPLOYEES WITHIN ORGANIZATIONS

Though viewed as a key aspect of mentoring [1], knowledge transfer has been primarily examined at the interfirm level [21], at the interdepartmental level [22, and at the team level [23]. [24] Suggest that much research on knowledge transfer has a more macro focus, examining the transfer of knowledge between and within organizations. Knowledge management articles highlight knowledge transfer as a key mechanism for organizational success, yet a gap exists between practice [25] and formal research [26, 24]. A key emphasis of research in knowledge transfer should be on the contribution of individuals to the process [24]. Little research in the knowledge management literature, however, has explicitly tested mentoring as a means by which knowledge is transferred among individuals [26].

Mentoring saves money, retains workers, builds leadership, and growth talent

Mentoring contributes to employee growth and tenure. In the long run, a well-organized and managed program can save the company thousands of rands.

- **Reduced turnover and recruiting costs.** Mentoring relationships can help retain talented people because they have a stronger commitment to the organization [27]. Talent remains much less likely to leave if they feel supported in their work and made aware, for example, of new opportunities that their mentor suggests. It's not unusual for organizations to hear that their strong mentoring program attracted new talent.
- **Assistance in transferring knowledge from the retiring workforce to new workers.** Many mentoring relationships help younger employees learn from those who will retire soon. Pairing junior staff with more senior staff can reinvigorate the enthusiasm of senior employees as they transfer crucial knowledge to the next generation of workers. This reduces the loss of the tacit knowledge from seasoned veterans leaving the workforce.
- **Helping employees learn skills and gain knowledge.** Mentoring is an excellent example of informal learning, which is the way people learn 80% of the time in the business world (Schooley et al, 2010) This referencing style is inconsistent with the rest of the citations. Be consistent!. A mentoring program reduces training costs due to the mentor/mentee informal learning relationship, which often deals with content one-on-one that otherwise would be covered in a formal course. It also brings new employees up to speed quickly in those first few months of employment. The chief learning and development officer in a global consulting firm confirms the value of mentoring as a learning tool: "People grow more with human interaction on the job, and we are trying to bring that to all our employees. The best way to learn is from a fellow professional.

  Assistance in career growth, building leadership capacity, and increasing bench strength. Mentees can put their learning on a fast track with mentoring. If they're headed toward management, for example,

the mentoring may focus on becoming a better leader and manager. When the mentor shares her own experiences, gives advice, and suggests readings, online courses, or other experiences to help other employees move toward their goals, she builds her own leadership skills in the process. Enhanced bench strength in company leadership ensures successful succession planning and increases productivity.

- **Increasing knowledge and insights about other employees.** Mentoring allows mentors to work with employees of different ages, backgrounds, values, styles of working, and professional expertise. This relationship breaks down barriers and informs mentees about other areas of the business. Mentors increase their employee network at different levels and know more about what's going on in the organization.

Mentoring has this remarkable effect and impact on retention? Some of the mechanisms, which have been documented, include:

• It points people towards internal rather than external job opportunities. (On average, only one in five employees is likely to look first within their current employer for their next job; of people, who are in mentoring relationships, this proportion rises to nearly five out of five.)

X. CONCLUSION

Retaining good employees is critical to a firm's long term success. And in the engineering and construction markets, employee retention is especially serious since the job market is tight and competition is fierce for top candidates. When you add the costs of recruiting and recruiting employees, the financial impact alone is staggering. Some studies estimate that losing an employee costs a company 100% of that employee's salary. When reduced efficiency, lower effectiveness, workforce instability and lost productivity are added to the cost to find and train a new employee, the stakes become high. Companies simply cannot afford to ignore employee retention.

Retaining organizational knowledge in the face of changing workforce demographics is a complex challenge that requires simultaneously confronting the problems created by an aging workforce, a shrinking talent pool and increasingly restless employees. It seems that the issue of mentoring and human resource development in construction organizations can generally be considered as a good field of research and vast topics of research can be defined in this regard.

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Awareness and Utilization of Construction Videos in the Teaching of Construction Technology Courses in Ghana

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Abstract **- This study explores the use of construction videos as an educational tool in the teaching of construction technology courses in Ghana. The objectives were to find out the g. The study mostly used quantitative data. The population and sample size comprised lecturers who handled the courses from the first to final years' in the Higher National Diploma Building Technology programme in the top five Polytechnics namely; Accra, Kumasi, Takoradi, Koforidua and Cape Coast. Cluster sampling technique was used in selecting respondents. Structured interview in the form of questionnaires was used with 100% response rate. The findings revealed that, the 100% awareness of construction videos were; megastructure world's tallest hotel, formwork to columns and beams, building technology industrialised building system and modern home construction technique. Most of the respondents used construction videos from downloads to teach which followed by those who access it online. The least respondents refer students to watch it during teaching. Level 100 had substructure, superstructure walls and columns, and retaining walls videos mostly used in teaching. Level 200 had staircase, roof, framed structures construction videos fairly used in the teaching of construction technology course. Level 300 had industrialised building system, precast and road videos used in teaching. It is however recommended that project consultants who work on projects to be executed by top class contractors should add a draft in the conditions of contract that the project would be videoed for educational purpose.**

Keywords **- building technology, construction videos, construction technology courses, Polytechnics, teaching.**

1.0 INTRODUCTION

The history of using videos in teacher education in the world especially in the United States goes back to the 1960s with the availability of portable video equipment and the emergence of videos as an instructional tool [1]. In the construction industry, the use of construction videos is not new and it been used to record construction operations, construction equipment, building systems or components, building structures, give tours of buildings, record interviews of construction professionals or other management team members, and beyond [2], [3], [4], [5]. The complexity of construction projects, with large-scale buildings and structures, the use of new construction methods and materials, together with the need to optimize their in-service performance and durability over time, all have a bearing on different aspects that need to be taken into account when training future engineers [6]. The construction industry is also very dynamic allowing for new construction methods, materials, among others. This means that constantly using traditional methods of teaching would not help learners of today because of the rapid changing of the industry every now and then.

Construction videos as an instructional tool provide valuable insight into teaching any course and its complex nature and present examples for the purpose of professional training and development. Using construction videos in professional training and development does not only benefit instructors but also learners offering construction related programmes [5]. The some of the ways of learning construction are through competency based training where students are assigned to live or going projects, site visits or field trips and during industrial attachment. The challenge is that only an aspect of construction processes or components would construction students have hands on because of the time student are assigned. But when the construction projects are videos, all aspects of the construction processes and other components can be seen and made available to students for effective teaching and learning.

For students, using construction videos allow them to access the material on request and controls in it in terms of start, stop, and speed of videos. The videos can be watched inside or outside of the classroom environment anytime the users want to learn from it [5], [7]. Videos can focus on particular aspects of teaching or allow teachers to evaluate their own teaching style to make teaching and learning very effective [8], [9], [10], [11].

Modern advancement in technology has resulted in making videos reasonably becoming cheap and widely available for use in such different situations as microteaching, video cases, and modeling expert teaching [12]. The flexibility of videos is another factor that makes the videos very appealing. There exist some computer applications that make the construction videos possible to edit it or reassemble the videos in any manner and to use them to launch an open-ended discussion. In addition, use of videos allows instructors to present examples of teaching or make connections with the theory being studied [1], [13].

1.1 Overview of construction technology courses

The Higher National Diploma (HND) syllabus use for the Building Technology programme in Ghana approved by the National Board for Professional & Technician Examinations (NABPTEX) has all the levels offering construction technology courses. In other words, from first to final year thus level 100 to 300 in Ghana where HND Building Technology is offered learn construction technology. The details provided below show an overview of the construction technology courses for the various levels.

Level 100: Introduction to principles and forms of building, functional requirement of building and the building elements, traditional building system, substructure construction and timber hollow floors constructional, superstructure walls and columns, retaining walls construction. Level 200: Framed structures, upper floor design and construction, staircase, roof, finishes and doors and windows.

Level 300: Students are exposed to recent developments in rationalizing the construction process by introduction of mechanization into the construction and related element of civil engineering construction. The typical areas of the course include the following: industrialized building systems, prefabrication, pre-casting, erecting and jointing of elements and components, road construction, setting out of roads and services.

1.2 Construction videos and possible teaching areas

There are numerous construction videos that are available online as one google it and also at YouTube for use in construction or engineering education. More construction videos can be viewed online through google search engine and also at YouTube as it is becoming an educational tool to enhance learning in innovative ways [14]. YouTube is popularly known and has emerged as a popular video-sharing web site upon its creation [15]. The videos on YouTube can be downloaded and also formatted as flash videos so that they can be stored and retrieved without loss of quality [16]. Users can search for any subject of study and watch the construction videos or other videos upon request. [15], [17]. Table 1 below presents some construction videos the researchers had online through both at the google search engine and also at YouTube that can be used in the teaching of the construction technology courses of the HND building technology programme.

Table 1: Sources of some construction videos and possible teaching areas

S/No.	TITLE OF CONSTRUCTION VIDEO	POSSIBLE TEACHING AREAS IN CONSTRUCTION TECHNOLOGY	SOURCE
1	The Palm Island, Dubai UAE - Megastructure Development	Building on island, foundation construction, superstructure construction	[18a]
2	Megastructure world's tallest hotel: Berj Al Arab – Dubai	Foundation piles, Precast structures, concrete structures, Curtain walling, cantilever construction,	[19]
3	Foundations	Site preparation, excavation, concrete in foundation, pile foundation, blockwork in foundation, types of foundation: raft foundation, stepped strip foundation, reinforcement in foundation.	[20a]
4	Roof structure	Roof types: flat and pitch roofs, roof types: lean-to roof, purlin roof, couple roof, roof	

		members: rafters, purlins, hangers, struts, ridge board, roof joint example scarf joint, roof cups, overhangs, roof trussess	[20b]
5	Formwork to columns and beams	Preparation of formwork, setting out formwork and support for columns and beams, checking alignment of formworks	[18b]
6	How to Use Rebar	How to fix starter bars, connection of base to main column	[18c]
7	3D Animation of the construction of a Multi-story Building	Stages of construction: excavation, concrete in foundation, concrete frame structure, reinforced concrete, reinforcement, formwork, alignment of the structure	[18d]
8	How To Frame a Window and Door Opening	Construction steps to create opening in doors and windows	[18e]
9	Buildtrade steel construction process	Preparation foundation for steel structures, installation of steel structures	[18f]
10	Column Shuttering	Fixing column shuttering, setting out, marking positions of columns	[18g]
11	Structural Steel Connections	Steel structure, steel sections, installation of steel structures	[18h]
12	Suspended slab and beam	concrete frame structure, reinforced concrete, reinforcement, formwork, beam and slab connection	[18i]
13	Building a House in Thailand - Start to finish	Foundation, frame structure, roofing, blockwork, step by step in building a house, plastering fixing of ceiling	[18j]
14	Retaining Wall - Construction Sequence	Sequence of constructing retaining wall, foundation reinforcement and concrete works, alignment of structures and constructing long retaining wall in phases	[18k]
15	Building Technology 1 Project 2 - Industrialised Building System (IBS)	Examples of industrialised building system, precast concrete, hollow floor construction, upper floor construction, precast wall, roofing structures.	[18l]
16	Building Technology IBS System	Prefabrication, components, installation, precast concrete, steel truss, roofing IBS structures	[18m]
17	Modern Home Construction Technique	Foundation, timber structure, joining member together, upper floor construction, applying wall finishes	[18n]

2.0 RESEARCH METHODS

Research approach: in achieving the research objectives by finding out the awareness and utilization of construction videos in the teaching of construction technology course and to gather the necessary data while overcoming other challenges such as geographical location of respondents, this study mostly used the quantitative research approach.

Sampling technique: Cluster sampling was used in selecting respondents. This was found to be the most appropriate technique that has the lecturers who handled construction technology courses of the various top Polytechnics scattered in the country to be represented.

Population and sample size: The population is composed of lecturers who handled construction technology courses from level 100 to level 300 in the Building Technology Department of the top five Polytechnics in the 2015/2016 academic year. The top five polytechnics used for the study were Accra, Kumasi, Koforidua, Takoradi and Cape Coast. It was based on the current ranking of tertiary institutions which was done in 2016 by the University Web Ranking in Ghana. Each polytechnic has three classes or levels. So the five polytechnic will have a total of fifteen (15) lecturers. All the population was used as sample size although some lecturers teach both classes in the Polytechnics. Each class was assessed separately.

Survey Method: structured interview in the form of questionnaire was used as the survey method. The study adopted the telephone call approach which was considered the best option given the geographical spread of the top five polytechnics across the country. The telephone interview approach saved time and resources that was not possible in the case of focus group discussion approach. Each interview lasted for about 30 minutes with a few exceptions. Fifteen (15) questionnaires were administered to the respondents of the various levels and all were received representing 100%. It was structured in three main areas namely, the background of respondents, awareness and utilization of the construction videos in the teaching of construction technology course. To enhance the credibility of this study, efforts were made to ensure accurate results are obtained. That included making sure all respondents were lecturers who teach the construction technology course to construction students, meaning they have sufficient knowledge about the questions asked. Also, they were very much aware of the context of the study and they prepared and willing to talk about the subject being studied.

Data Analysis: Descriptive statistics was used for the study. Mean score item and standard deviation (SD) was used to evaluate the usage of construction videos in teaching. 5 points Likert scale was used from almost always to never use in teaching. Where 1 –Never, 2 – Seldom, 3 – Sometime, 4 – Often, 5 – Almost always**.**

The mean item scores of the variables were calculated using the formula below;

$$MIS = \left[5 - \frac{\sum(f \times s)}{N} \right] \; (1 \leq MIS \leq 5)$$

Where MIS is the mean item scores, f is the frequency of responses to each rating (1-5), s is the score given to each variables by the respondents (ranging from 1 to 5), and N is the total number of responses concerning that variable. Data was represented in frequencies.

3.0 FINDINGS AND DISCUSSION

3.1 Respondent's background

Eleven (11) of the respondents representing 73% were lecturers while two (2) representing 13% were senior lectures with one (1) of the respondent representing 7% was associate professor who handled construction technology courses in the various polytechnics surveyed. 10 respondents had teaching experience of 0-5 years representing 67% which is the highest. This shows that all the respondents had teaching experience in the field of study. The rest of the respondents (5) had 6-10 years of teaching representing 37%.

3.2 Awareness of construction videos

All the fifteen (15) respondents' representing 100% were aware of the existence of construction videos that can be used in the teaching of construction technology course.

Table 2 below indicates the individual construction videos awareness level from respondents. From the survey, the videos that had 100% awareness level were megastructure world's tallest hotel: Berj Al Arab – Dubai, formwork to columns and beams, building technology IBS system and modern home construction technique. This shows that respondents were more focus on some as compare with others.

Table 2: Awareness of construction videos

S/No.	CONSTRUCTION VIDEO TITLE	Awareness			
		Yes		No	
		No.	%	No.	%
1	The Palm Island, Dubai	14	93.3	1	6.7
2	Megastructure world's tallest hotel: Berj Al Arab – Dubai	15	100.0	0	0
3	Foundations	15	100.0	0	0
4	Roof structure	14	93.3	1	6.7
5	Formwork to columns and beams	15	100.0	0	0
6	How to Use Rebar	5	33.3	10	66.7
7	3D Animation of the construction of a Multi-story building	1	6.7	14	93.3
8	How to frame a window and door Opening	13	86.7	2	13.3
9	Buildtrade steel construction process	5	33.3	10	66.7
10	Column shuttering	6	40.0	9	60.0
11	Structural steel connections	13	86.7	2	13.3
12	Suspended slab and beam	13	86.7	2	13.3
13	Building a house in Thailand - start to finish	5	33.3	10	66.7
14	Retaining wall - construction sequence	13	86.7	2	13.3
15	Building Technology 1 Project 2 - Industrialised Building System	14	93.3	1	6.7
16	Building Technology IBS System	15	100.0	0	0
17	Modern home construction technique	15	100.0	0	0

Source: Fieldwork 2016

Table 3: Usage of construction videos in teaching of construction technology

S/No.	Teaching areas for different levels	Mean	SD	Rank
	Level 100			
1	Building components	1.60	4.04	4
2	Substructure	3.20	4.06	1
3	Timber hollow floor	1.20	7.81	5
4	Superstructure walls and columns	2.60	3.61	2
5	Retaining walls construction	2.20	2.77	3
	Level 200			
1	Framed structures	2.40	3.57	3
2	Upper floor design and construction	1.20	7.81	5
3	Staircase	2.80	3.96	1
4	Roof	2.60	3.61	2
5	Finishes	2.20	2.77	4
6	Doors and windows	1.20	7.81	5
	Level 300			
1	Rationalizing the construction process	1.60	4.04	5
2	Industrialized Building Systems	3.20	4.06	1

3	Prefabrication	1.20	7.81	6
4	Pre-casting	2.60	3.61	3
5	Road construction	2.60	3.43	2
6	Setting out of roads and services	1.80	3.00	4

Source: Fieldwork 2016

3.3 Usage of construction videos in teaching of construction technology

Table 3 reveals that, level 100 had construction videos used for the teaching of construction technology course. Substructure videos was the highest record teaching area with mean score item of 3.20. It followed with superstructure walls & columns and retaining walls construction videos with 2.60 and 2.20 mean score respectively. Level 200 had staircase, roof, framed structures construction videos fairly used in the teaching of construction technology course. The level 300 had IBS, precast and road construction videos used in the teaching of construction technology course. This shows that respondents were able to search for various construction videos online and also at YouTube for use as it become an educational tool to enhance teaching and learning in innovative ways. [15], [18], [19].

3.4 How construction videos are used in the teaching of construction technology courses

Nine (9) of the respondents representing 60% used construction videos from downloads. This means that respondents have a copy of the construction videos on the computers for use in the teaching of construction technology courses while four (4) representing 27% access it online during lectures where respondents are provided or have access to internet. Two (2) of the respondent representing 13% which is the least, refer students to the construction videos during the teaching of the construction technology course and direct students to search for it and learn from it themselves as illustrated in figure 1 below. This indicates that the construction videos online can downloaded and edited or formatted as flash videos so that they can be stored and retrieved without loss of quality. Users can refer to it anytime it is needed in the teaching or learning of the construction technology course [17]. In addition, most of the respondents who used construction videos pointed out that, not every topic under study should have construction videos used because open floor discussion on the subject area because it takes more time in the teaching of the construction technology course. It makes others refer it to the students to search for it and learn from the particular construction videos shown them by the lecturer.

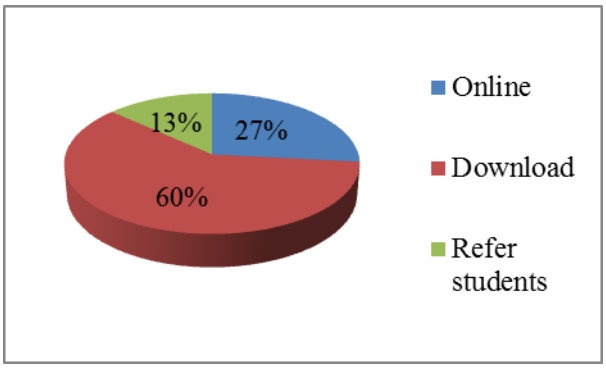

Figure 1: How construction videos are used in teaching

4.0 CONCLUSION

There are numerous construction videos that can be used as an educational tool available online in the google search engine and also at YouTube for use in the teaching of construction technology courses. The study extracted seventeen (17) samples construction videos through internet and other downloaded sources that can be used in the teaching of construction technology courses in the Higher National Diploma in Building Technology programme. These are: (1) The Palm Island, Dubai, (2) Megastructure world's tallest hotel: Berj Al Arab – Dubai (3) Foundations (4) Roof structure (5) Formwork to columns and beams (6) How to Use Rebar (7) 3D Animation of the construction of a Multi-story building (8) How to frame a window and door Opening (9) Buildtrade steel construction process (10) Column shuttering (11) Structural steel connections (12) Suspended slab and beam (13) Building a house in Thailand - start to finish (14) Retaining wall - construction sequence (15) Building Technology 1 Project 2 - Industrialised Building System (16) Building Technology IBS System and (17) Modern home construction technique. It also provided associated possible teaching areas in the teaching of construction technology courses. The teaching areas identified ranges from substructure to superstructure construction and beyond. The teaching areas were purely for construction education. They show a step by step construction process in the subject area understudy. All the levels thus from 100 to 300 had a possible construction video that can be used in the teaching of construction technology courses.

Respondents were fully aware of the existence of construction videos in the construction industry for use for level 100 through to level 300 who offer Higher National Diploma in Building Technology programme in the Polytechnics of the country. However, its usage was not done always often to

expose learners to it but was fairly utilized. Most of the respondents used construction videos from downloads which followed by access online with the least that refer students to it during teaching. This shows that there would be room for open floor discussion where every learner get access to it for better understand of the subject area under study.

It is however recommended that the project team members led by the project consultants who work on mega structures or projects to be executed by top class building and civil contractors should include a draft supplementary condition to be included in the existing conditions of contract that the project to be constructed would be videoed to be used for educational purposes.

All stakeholders of construction education in Ghana, including the National Accreditation Board (NAB), National Board for Professional and Technician Examinations (NABPTEX) and educational curriculum development consultants must all come together and work hard to review the construction technology curriculum to reflect current developments in terms of content, structure and provide a comprehensive teaching method. They should also include modern teaching methods such as the use of current construction videos in the teaching construction technology courses. This will enable both lecturers and new lecturers who are not familiar with modern construction videos also prepare adequately for the construction technology course.

Developer of these construction videos should also consider the use of modern tools in the preparation of construction videos to be used for education purposes. The construction videos surveyed were more of 2D and producers can consider 4D or other more production practices to video current construction videos. There is therefore the need to establish and create a new clear website for construction students and other teachers all over the world to view free modern construction videos for their studies rather than leaving it in the general internet based system.

5.0 FUTURE RESEARCH

Future research must focus on the role construction videos play to enhance the practical or technical skills of construction students in Ghana.

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Measuring the Level of Maturity of the Construction Industry to Provide Feedback to Engineering Education: A case of Botswana

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Abstract **- Engineering education requires constant feedback from various sources of assessment to sustain the level of proficiency of professionals. This is often achieved by assessing the professionals themselves. It can also be achieved by proxy i.e. by assessing professionals' effort at an organisational or industry level. For this type of assessments, models have been developed to investigate the level of proficiency of the professionals through maturity modelling. Construction Industry Maturity (CIM3) is one such model, which has been developed and tested to measure the maturity level of the construction industry in Guyana. The Analytic Hierarchy Process (AHP) technique was used to compute the scores of experts who participated in the study and results provided insightful findings. This paper reports findings of a replicated study conducted in Botswana. The findings indicated that the construction industry in Botswana had a maturity level of 48.1%. Though the results must be treated with the caution of some inherent limitations, they provided an insight about the maturity level of Botswana's construction industry and where engineering education should focus i.e. increasing the capability levels of all the six key areas assessed namely cost, quality, health and safety (H&S), human resource (HR) management, environment and procurement. Results indicated that concerted effort was needed in the area of H&S and HR, which came out worse on the maturity level scores and when these and other deficient practice areas are attended to, the industry has a potential growth of 51.9% .**

Key words **- construction industry, maturity model, performance, Botswana, engineering education**

1 INTRODUCTION

Sustained engineering education requires feedback from various facets of the industry. This could include direct competence assessments of professionals working in the industry or it could be, by proxy, based on inferences resulting assessing the performance of the industry. The latter is based on the notion that if an industry is efficient and effective, for example, delivers projects within stakeholders' expectations, then the proficiency levels of the personnel working in the industry is satisfactory. This type of assessment may also be useful because it depicts the effectiveness of the aggregate contribution of the decisions made by professionals in processes and practices relating to design, planning, construction and maintenance of the engineering facilities. The feedback from the assessments is therefore useful in engineering education at undergraduate, postgraduate and continuous professional development (CPD) level, especially if it focuses on the areas that are identified with low proficiency.

Assessment of the performance of the construction industry by researchers and policy makers has traditionally been based on macroeconomic indicators and aggregate productivity levels. The common macro-economic indicators are the gross domestic product (GDP) contribution by the construction industry while for productivity it is the 'labour productivity growth rate'. Given the lack of detail from the two indicators and possible measurement errors [1], alternative methods of assessing the construction industry have been sought. Maturity models such model as the Construction Industry Macro Maturity Model (CIM3) have been developed and tested to provide industry assessment. The CIM3 model is based on the Capability Maturity Model (CMM) which is extensively applied in the software manufacturing industry and uses the concept of process maturity. While the application of the CIM3 is in its infancy, it was selected over other macro models for use in the study to assess the level of maturity of the construction industry in Botswana because it has a simple yet robust scoring system which allows for the tracking and comparison of maturity over time; and assesses maturity according to parameters in line with project performance.

This paper reports findings of a study whose objectives were to first, to quantitatively measure the maturity of Botswana's construction industry in six selected key practice areas; and second, to highlight the implications of maturity assessment as possible feedback to engineering education. The rest of the paper is divided into five sections with the next section providing a brief profile of Botswana's construction industry. The second section discusses literature relating to maturity modelling and in particular the CIM3 model. Section three of the paper describes the research approach used for the study while section four of the paper presents and discusses the study findings and their implication to engineering education. The paper ends with a conclusion.

2 CONSTRUCTION INDUSTRY IN BOTSWANA

Botswana is located in the southern part of Africa. It is a relatively large country covering an area of 582,000 km^2 but with a small population of 2.04 million inhabitants [2] and therefore a sparsely populated country with approximately three inhabitants per Km^2. In 2013, its workforce was estimated at 389,665 employees, of which approximately 47% worked in the public sector [3]. Botswana's GDP stood at P145, 714 million (US$ 14,054 million) in 2015 [4].

Botswana will be 50 years old in September 2016. It is fair to say that its construction industry is relatively young when compared to other industries in the world. However, it should be viewed as a proud industry which has turned what may be described as a remote colonial outpost at independence in 1966 into a flourishing network of good quality infrastructure facilities in form of paved road network; water reticulation systems; modern residential and commercial buildings; and international aerodromes, to mention a few. As of 2014, the sector's GDP stood at P9, 526 million (US$918.8 million) which is equivalent to 6.5% of the total national GDP [4]. Latest employment statistics indicated that in 2012, the sector employed 23,650 people or 6.1% of the work total workforce [3].

Like any persona, human or artificial, growth often comes with challenges and the industry has experienced a number of challenges some of which are caused by external forces while others are of its own making. Over years the industry's activity has intermittently slowed down due to various reasons including drought conditions that caused water shortages. In other instances it has been a victim of effects of the world economic recession which led to its largest client (the government) scaling down its construction procurement activities and sometimes cancelling projects altogether due to reduced diamond export revenues.

The industry has also been challenged within. Over years its delivery efficiency and effectiveness have been called into question. Research studies have questioned the industry's project delivery efficacy, for example, [5] painted a picture of an industry that lacked the basic ingredients, for example, there is lack of institutional setup which in turn lead to a lack of industry leadership and vision; poorly designed indigenous development programmes to uplift the local contracting capacity; and lack of work ethic and fiscal discipline by both the consulting and contracting fraternity. Almost a decade later the situation has hardly changed as a study by [6] revealed that projects were still being delivered in an unsatisfactory manner. The study found that based on the sampled projects within a five-year period only 8% had been completed on time and within cost, while 13% of them had been abandoned. Mass media reports (e.g. [7]) and court cases (e.g. [8],[9]) also continue to indicate project delivery challenges in form of escalated costs, massive time overruns, poor quality infrastructure and questionable award of tenders, especially in the public sector which incidentally forms over 65% of the total value of tenders of the sector [10]. Such reports motivated an investigation into Botswana's construction industry level of maturity.

3 MEASURING INDUSTRY MATURITY

In this section the basic concept of measuring industry maturity and in particular the CIM3 model are briefly discussed.

3.1 Maturity Modelling

Maturity modelling is based on the premises that there is an evolutionary growth path with a set of thresholds through which a process must transition to reach maturity, for example, the Capability Maturity Model (CMM) is based on five thresholds of maturity [11]. In level one and two, a process is chaotic or ad-hoc and must transition to being repeatable, respectively. At level three and four, it is defined or standardized followed by being managed (i.e., measured and controlled), respectively. Ultimately at level five the process is optimized, that is, it is continuously improved via feedback and through the use of innovative ideas and technologies.

The utility gained from process maturity modelling has been investigated by various researchers (see e.g. [12],[13]). In software development, for example, it was found that improved process maturity had a net effect of reducing the overall software development cycle as well as reducing the development effort and cost [14], whereas in the field of project management Ibbs and Kwak [15] found that higher levels of project management maturity might result in improved project performance along the iron triangle. This is what led scholars to migrate the idea to the construction industry.

3.2 Construction Maturity Models

The concept of process maturity has been applied in the construction industry and has produced two categories of maturity models at a micro (or process) and the macro (industry wide) level. Examples of micro level maturity models include the process improvement for construction enterprises (SPICE), the construction supply chain maturity model (CSCMM) and the organizational project management maturity model (OPM3). Their attributes are summarised in Table 1. Briefly, the SPICE maturity model assesses construction processes related to design, construction and maintenance within construction companies. The CSCMM maturity model assesses construction processes related to their supply chain management to improve the operational efficiency of their supply chains [16]. The OPM3 maturity model provides an assessment of the organisation maturity in conducting project management process through a comparison with best practices.

At the macro-level of the construction industry two models pervade the maturity assessment landscape. First is the FIMG maturity model which assesses the construction industry's

maturity along three dimensions i.e. markets, technologies and structures [17].

The FIMG uses fuzzy set theory, the industry maturity grid (IMG) and the analytic hierarchy process (AHP) to provide a weighting mechanism of importance. Knowledge elicitation is then used to determine the maturity of the construction industry with respect to each characteristic, and fuzzy set theory is used to account for the uncertainty associated with the knowledge elicitation process. On the other hand, the CIM3 maturity model is based on the improvement of key practices of the industry as described in the next section.

3.3 The CIM3 Model

The CIM3 model is based on the assumption that there are several processes (or/and practices) that are executed when delivering a project, in the construction industry (CI), perhaps akin to the knowledge areas of the PMBoK [18]. In other words, to deliver a project the construction industry players must implement several processes at the same level of sustained competence, for example, perform efficiently and effectively processes relating to the achievement of the 'iron triangle', health and safety or procurement management. In the CIM3 model terminology, these are called key practice areas (KPAs) as shown in in Figure 1.

Each KPA will be performed in the industry at a certain level of maturity. Therefore, the combined level of maturity of the KPAs determines the level of maturity of the construction industry (CI). The word 'key' means that the selected KPAs are dominant when compared to possible processes in the industry i.e. they are quite sufficient to determine the maturity of the industry. A study was conducted in Guyana by Willis and Rankin [19] to measure the maturity of the construction industry using the CIM3 model was, for example, based on four KPAs namely cost, quality, human resource (HR) and health and safety (H&S) management practices. These authors viewed these four KPAs as sufficient to measure the maturity of the industry. However, they also recognised that the four KPAs did not have the same level of importance in the CI bouquet.

Weights were then computed to determine their importance or contribution to Guyana's construction industry maturity.

Table 1: Summary of Attributes of Some of the Micro and Macro Models used in the Construction Industry

Assessment Level	Maturity Model	Focus	Operationalisation	Maturity levels	Utility	Key Limitations
Micro (or organisational) Assessment	SPICE	Maturity of construction design, construction and maintenance activities	Key processes are assessed against five "process enablers" to determine if each of the key processes has reached capability	Five levels – ad-hoc, repeatable, defined, managed and controlled.	Provides an indication of the maturity of processes in order to prioritise process improvement	Treats all organisations as the same and organizational processes as being equal
	CSCMM	Maturity of supply chain processes	Supply chain management is assessed along three dimensions (functional, project and firm) and according to four categories of assessment (process, technology, strategy and value).	Four levels – ad-hoc, defined, managed and controlled.	Construction supply chain certification for partnering	Deals with supply chain (or procurement) only yet the construction is more than procurement.
	OPM3	Maturity of portfolio, program and project	Directory of best practices number 500 organizational project management best practices and expected specific outcomes which are assessed using indicators	Four levels- standardize, measure, control and continuous improvement	Provides a measurement of maturity in organizational project management	Treats all organisations as the same and organizational processes as being equal
Macro (or industrial)Assessment	FIMG	Maturity of markets, technologies and structures	Uses fuzzy logic in conjunction with the industry maturity grid (IMG) which is a qualitative model and analytic hierarchy process (AHP) for weighting industry characteristics t	Two levels- Immature (0) and mature (1)	Useful for highly developed industries which are seeking to conquer foreign markets	No transitional state between mature and immature; dimensions used for assessment are far removed from project performance
	CIM3	Maturity of key practice areas (KPA)	Solicits experience industry experts to assess the KPAs and the analytic hierarchy process (AHP) may be used to weight the KPAs	Three levels- immature (0.000-0.333), transitional (0.333-0.666) and mature (0.666-1.000)	Useful for both industrialised and developing industry; can be replicated and key practice areas increased to suit context; possible to conduct longitudinal studies	Subjectivity of the experts and the computation may be complex especially when weighting is included; three maturity levels may not be very sensitive to fine tune maturity levels

Sources: [7], [20], [16], [21], [22]

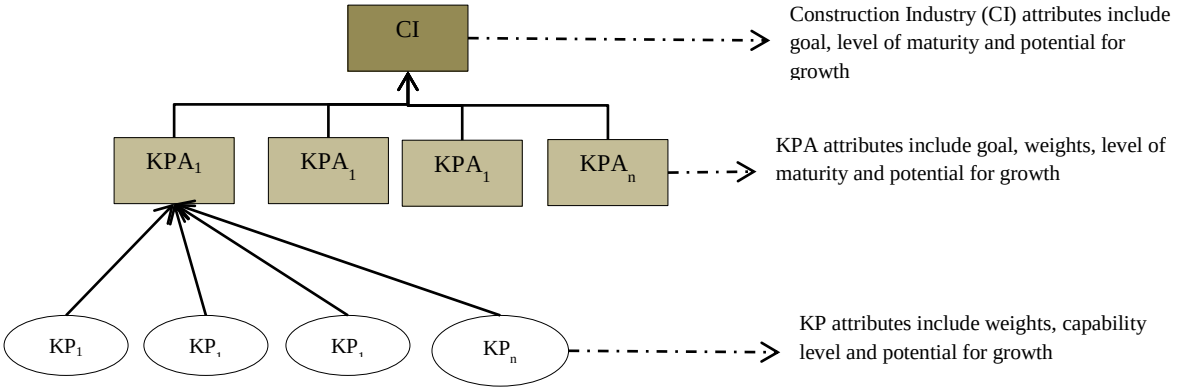

Figure 1: General structure of the CIM3
Source: adapted from [19].

Furthermore, each KPA has got an industry objective which contributes to the grand goal and maturity of the industry, for example, the objective of H&S is to deliver construction projects in manner that ensures safety of the workers in order to reduce the number of accidents while that of quality is to deliver construction projects at desired quality specifications. Therefore, if a KPA is mature this contributes to the elevation of the maturity of the industry. Each KPA is made up of several key practices (KPs) (see Figure 1). Therefore, the maturity score of each KPA is a product of the importance and the aggregate level of all capabilities of KPs.

The attributes of each KP include its importance (or weight) within the KPA and the level at which it is achieved in the industry i.e. the capability level of the industry and potential for growth. Maturity is measured using a three-tier threshold with the first level being the immaturity level which lies between $\frac{0}{3}$ (or 0) and $\frac{1}{3}$ while the transitional level is between $\frac{1}{3}$ and $\frac{2}{3}$. The mature level lies between $\frac{2}{3}$ and $\frac{3}{3}$ (or 1). If a KP is assessed with a score of zero (0) it is considered to be a non-existent (immature) practice in the industry while a score of one (1) means it is totally mature i.e. it is sustainably practiced in the industry. Ultimately, this means when a KP (or KPA and industry) is assessed to have a score of between zero (0) and one (1) then it has a potential for growth.

4 RESEARCH METHODOLOGY

The research approach involved three major stages. These included identifying a study group consisting of construction industry experts; identifying appropriate KPAs and KPs; and data collection and analysis. Each is discussed below.

4.1 Study Group of Experts

The study group was conveniently selected based on two aspects. First, the number of years of experience working in Botswana's construction industry had to be not less than ten years. Second, was the willingness of experts to participate in the study. While 14 experts who fitted the two criteria were approached only 12 participated in the study and their profiles are summarised in Table 2. They consisted of eight civil engineers, one electrical engineer, one mechanical engineer, one architect and one quantity surveyor. They worked in both private and public sector organisations; with average experience of about 17 years. The variety and experience of the study group was thought to have provided the desired insight for the study. All ethical aspects were taken care, including informed consent, voluntary participation and protecting the confidentiality of respondents.

4.2 Key practice Areas (KPAs)

The KPAs and KPs identified by Willis and Rankin's study [19] were adopted (cost, quality, HS and HR). However, two KPAs were added that of procurement and environment management (due to the brevity required in the paper the actual list of KPs has not been included in the paper but is available on request from the authors.

Table 2: Profile of the experts who participated in the study

Respondent No.	Highest Level of Education	Years of experience	Employment Position	Sector of Employment
1	Master's Degree	24	Director	Contracting
2	Master's Degree	20	Director	Contracting
3	Master's Degree	13	Project manager	Contracting
4	Master's Degree	10	Project coordinator	Contracting
5	Master's Degree	15	Project engineer	Consultancy
6	Master's Degree	14	Project engineer	Consultancy
7	Master's Degree	25	Project manager	Consultancy
8	Master's Degree	21	Director	Consultancy
9	Master's Degree	12	Senior engineer	Client organization
10	Master's Degree	16	Project coordinator	Client Organization
11	Master's Degree	18	Project coordinator	Client Organization
12	Post Graduate Diploma	19	Chief engineer	Client organization

Source: [23]

Given the Botswana project delivery landscape [24] and its sensitive environment [25], it was felt that the two should be added to provide a better insight of the project delivery maturity of the industry. In addition, literature sources were critically reviewed to obtain the appropriate KPs for the procurement and environment management practice areas.

4.3 Data Collection and Analysis

Three sets of data required for the study were sought from experts. This included weights depicting the importance of KPs; weights of KPAs; and the capability score (CS) for the capability level of the each KP. To get these data questionnaires were designed based on the study by Willis and Rankin [19]. To obtain the weights of each KP within the KPA, a pair-wise comparison was performed by each expert based on a decision making technique called Analytic Hierarchy Process (AHP) (for full description see e.g. [26]) for the KPs and KPAs. The use of the AHP pair wise comparison was preferred to, for example, the five point Likert scale as the AHP method is more reliable, accurate and consistent method of deriving weights of importance [19]). The comparison of the KPs was done using a nine-point scale of values, to express preference of one over another (or one KPA over the other). Table 3 shows the matrices which were developed from the six KPAs.

Table 3: Matrixes formed KPs and KPAs for pairwise comparison

KPAs (code used)	KPAs Comparison Matrix size
Cost management (CM)	9x9
Quality management (QM)	8x8
Health &Safety management (HS)	13x13
Human Resource (HR) management	13x13
Procurement (PR)management	13x13
Environment management (EM)	7x7

Source: [23]

The Table also depicts the number of KPs in each KPA for which experts performed a pair-wise comparison, for example, cost management had nine (9) KPs. To obtain the weights (importance) of the KPA within the industry a similar process was carried out based on a 6x6 matrix depicting the six KPAs. The final weight of each KP and KPA is achieved through the aggregation of individual judgments (AIJ) approach (see e.g. [27]). The capability score of each KPA was determined by expert completing a questionnaire which possessed six sections relating to the KPAs. The knowledge and experience of experts was presumed sufficient to reflect prevailing state of the construction industry.

Raw data from the questionnaire was entered in Excel worksheet and was analysed by computing the weights, maturity and growth potential in accordance with Equations 1 to 4 [19]

Level 1: MSConstruction Industry = Σ .....**Equation 1**

Level 2: MSKPA = Σ (MSKey Practice) X AHPKPA .....**Equation 2**

Level 3: MSKey Practice = CSKey Practice X AHPKey Practice.....**Equation 3**

$$GP=\frac{\text{Weight of a KPA – maturity score of a KPA}}{\text{Weight of a KP or KPA}} \text{ x } 100\% \text{.....}$$ **Equation 4**

where:

- MSKPA is the maturity score of a KPA,
- MSKey Practice is the maturity score of a key practice,
- MSConstruction Industry is the total maturity score of the construction industry,
- AHPKPA is the weight of importance of a KPA derived via the analytic hierarchy process,
- AHPKey Practice is the weight of importance of a key practice to the performance goal of its KPA derived via the analytic hierarchy process and CSKey Practice is the capability score of a key practice
- GP is the growth potential

5 RESEARCH FINDINGS AND DISCUSSION

The findings of the study are discussed in three sections namely the maturity level of KP, KPA and industry and the implication of the findings**.**

5.1 Importance and Maturity Level of the KPs in the KPA

This section provides the perception of the experts regarding the maturity of the KPs used in the construction industry in Botswana. The findings are anchored around two figures; one (a) indicating the importance of a KP within the KPA while the other (b) shows the maturity (shaded black) and potential for growth (shaded with zebra colours).

5.1.1 Cost Management (CM) Practices

Figure 2 (a) shows that nine KPs contribute to achieving the overall objective of delivering a project within budget. However, relatively speaking three KPs (CM5-monitoring of costs, CM7- prompt payments & CM9- cash flow forecast) were deemed very important as they contribute to more than half (0.2912+0.1930+0.1849=0.5791 or 57.91%) to the realisation of this objective. CM3 (consultant hour rates), CM4 (contractor equipment and labour rates) and CM1 (worker wage rates) were perceived as the least important KPs in the cost management bouquet.

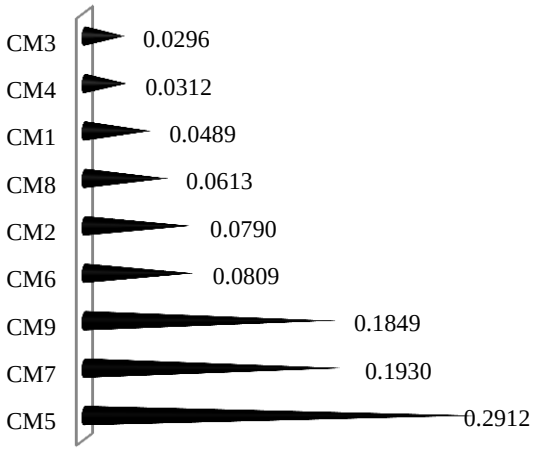

Figure 2(a) Weights (or importance) of cost management (CM)key practices

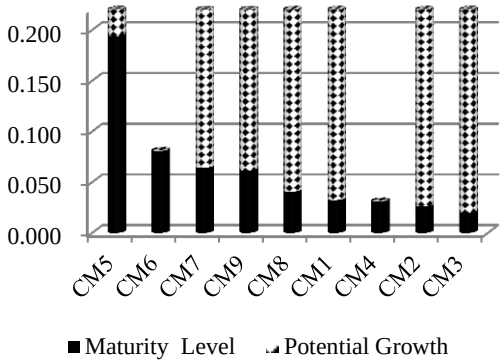

Figure 2(b) Maturity level and potential growth of cost management (CM)key practices

Figure 2(b) indicates that only two key practices (CM4-inputs rates & CM6-claims submission) were considered to be fully mature and with no need for further growth. However, the two KPs were not perceived as very important. While CM5 tops the list of mature KPs it is not fully mature and has room for growth. This is reflected in the desire by both the client and suppliers trying to work within the contracted amounts but yet often failing to realise this objective. The results indicate that due to the importance but low maturity of CM5, CM7, CM9 and CM8, the industry has to develop strategies for improving these practices.

5.1.2 Quality Management Practices

Figure 3(a) indicates that the quality management practice area had eight identified KPs and three of them (QM4-specifications, QM7- quality plans and QM6- inspections) were perceived as contributing to over half (0.5686 or 56.86%) to the objective of delivering construction projects at a desired quality while the three least important were QM1 (national building code), QM3 (total quality management) and QM8 (snag lists).

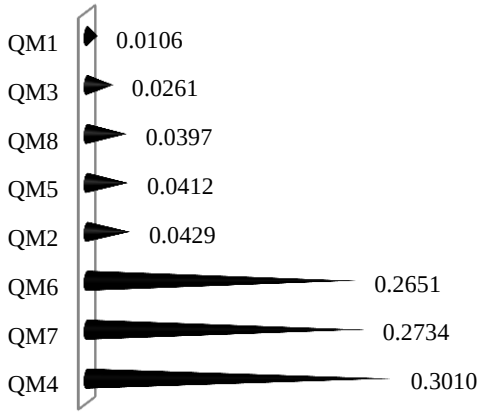

Figure 3(a) Weights (or importance) of quality management (QM) key practices

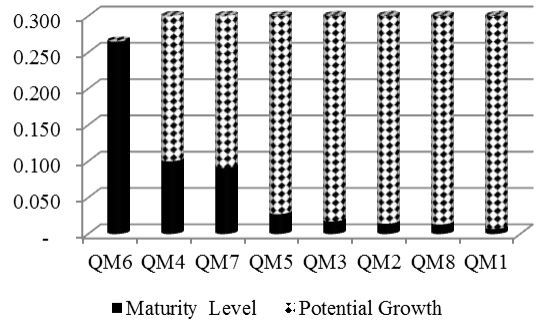

Figure 3(b) Maturity level and potential growth of quality management (QM) key practices

Figure 3(b) indicates that experts considered only QM6 as fully mature while QM4 and QM7 are in transitional stage that requires growth. The two having been identified as important, the findings send a message to the construction industry to put more focus on the duo to achieve and sustain the required level of maturity of project quality.

5.1.3 Environment Management Practices

Figure 4(a) shows the environment management KPA had seven KPs of which four (EM4-E-budgeting, EM6-implementation of E-plans, EM5- E-specifications & EM3-EIA) were considered very important in contributing to the objective of delivering construction projects in a sustainable way that preserves the environment. Experts were of the opinion that there is no need for specific environmental laws (EM1) to govern construction, perhaps because this is already covered in the EIA Act of 2011 [28]. They were also of the view that fines (EM7) were not really necessary at this stage of development for environmental 'polluters/destroyers'.

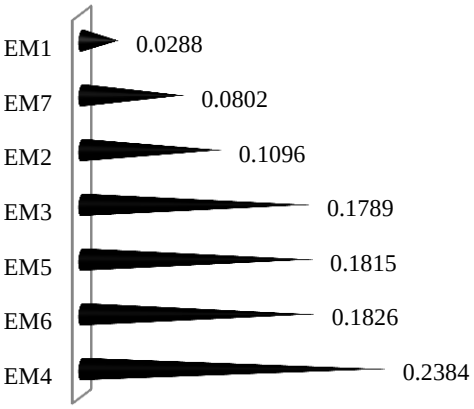

Figure 4(a) Weights (or importance) of environment management (EM) key practices

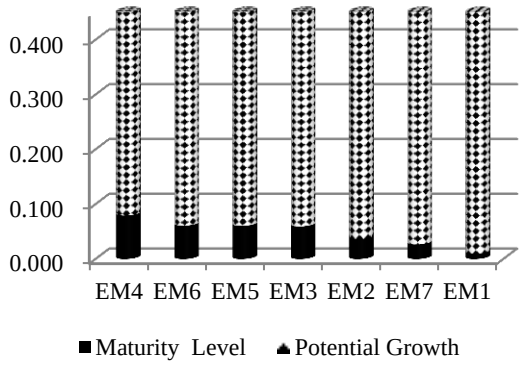

Figure 4(b) Maturity level and potential growth of environment management (EM) key practices

Figure 4(b) indicates that experts were of the view that none of the key practices has reached maturity. However, they perceived the four most important (EM4, EM6, EM5 & EM3) as being more mature, with some room for growth. EM1 and EM7 were immature but given their low level of importance, it is viewed as not a worrying phenomenon. In most jurisdictions of the world and coupled with effects of climate change embedding environmental issues is vigorously being advocated in engineering education [29]. The feedback from the assessment in this study is sending a similar call.

5.1.4 Human Resources Management Practices

Human resource (HR) management practice requires delivering construction projects in manner that ensures the efficient and effective use of industry's human resources. Figure 5(a) shows that one practice area alone (H6- skill assessment and evaluation) has an outstanding contribution (19.25%) to the objective followed by five others (HR11-equating jobs with competence, HR10-regualtion of professionals, HR4-skill assessment, HR2-matching jobs with skills, & HR7-on-job training). Competence feeds into many area e.g. productivity, reduced wastage and health and safety and hence the perception of its relative importance to HR management. HR8 (incentives) was considered least important perhaps due to the fact that the industry pays workers well above the minimum wage of P5.15 per hour [30]

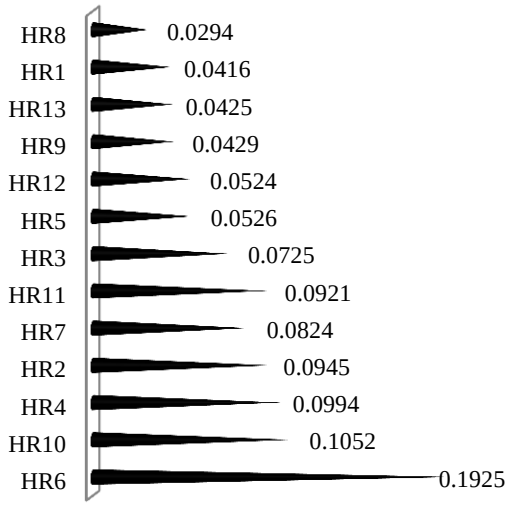

Figure 5(a) Weights (or importance) of human resources (HR) management key practices

Figure 5 (b) indicates that all KPAs under HRM are immature and require improving. The two that needed the greatest growth include the lack of a strategic plan (HR12) for determining the supply and demand of the industry's manpower needs. The second was lack of a monitoring mechanism (HR5) to track supervisor /work ratio.

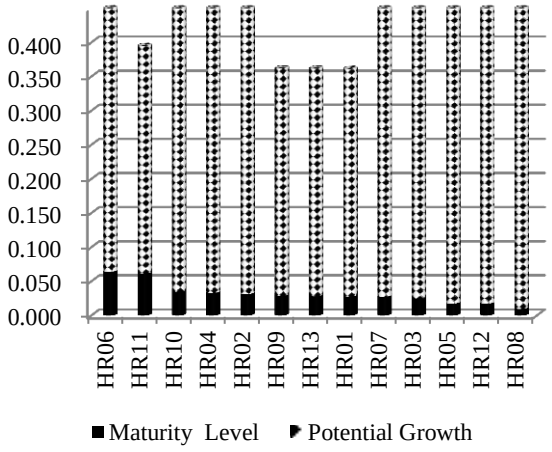

Figure 5(b) Maturity level and potential growth of human resources (HR) management key practices

5.1.5 Health and Safety Management Practices

Health and safety (HS) is one of the corner stones of the construction industry, an industry often described as 'dirty, dangerous, difficult, demeaning or destructive' [31]. Therefore, the main objective of the KPA is to deliver construction projects in manner that ensures safety of the workers in order to reduce the number of accidents. Figure 6(a) indicates that one KP is considered very important (H11-safety equipment provision) contributing to 21.0% of the total. The next four key practices are (H12-HS meetings, HS9-HS induction programmes, H13-HS national code & H5-control of substance abuse).

Figure 6(b) shows that H11 is almost a mature practice while the rest are in various levels of transition. The most immature KP and which was also considered not important is H10 which relating to the consideration of past HS performance during award of tenders. Botswana has not experienced disastrous levels of HS failures as those reported in the media in places like Bangladesh, India and recently in Kenya [32]. What this may imply is that other mechanisms are currently working and hence the perception that that rigour is not necessary.

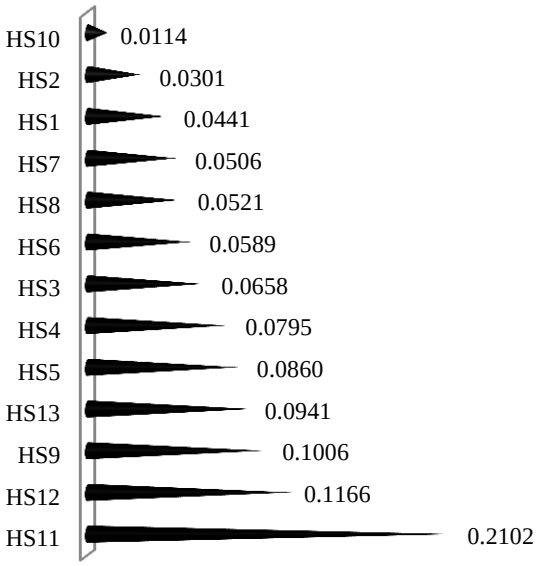

Figure 6(a) Weights (or importance) of health and safety (H&S) management key practices

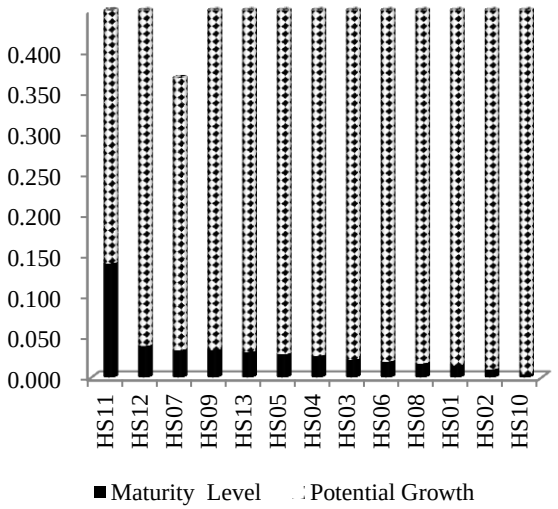

Figure 6(b) Maturity level and potential growth health and safety (H&S) management key practices

5.1.6 Procurement Management Practices

The objective of procurement key practice area is to procure construction goods and services in an effective and efficient manner. Out of the 13 KPs, one stood out as very important, PR5 (tender evaluation criteria) contributing 20.0% of the total KPs. Five others (PR12-perfromance bonds, PR1-

advertising tenders, PR4- specified mode of bid submission & P13-surety for payment of sub-contractors) are almost of equal importance. These are important aspects in any procurement system- but how mature are they?

Figure 7(b) indicates that PR5 is a well matured practice and the experts were satisfied that tender bids go through a rigorous evaluation process based on a pre-determined criteria. However, it is one thing to have a criteria and another to have an effective one or to be followed. A few court cases which have followed the tender evaluation process often tend to blur the good work done in the procurement regime if the industry, especially in the public sector. Other areas require growth and in particular PR2 (predetermined method designer selection), PR9 (relying on the iron triangle) and PR7 (alternative methods of procurement) though they were considered less important in procurement.

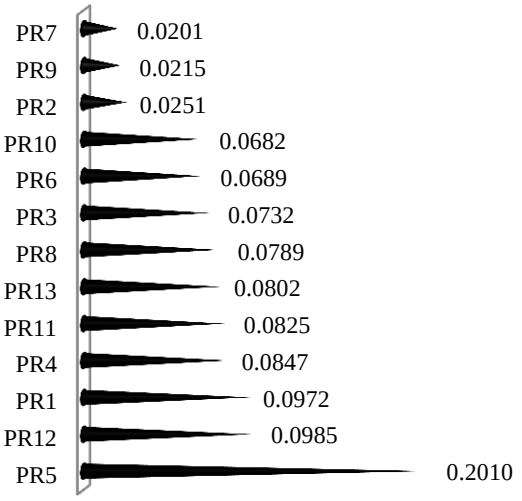

Figure 7(a) Weights (or importance) of procurement management (PR) key practices

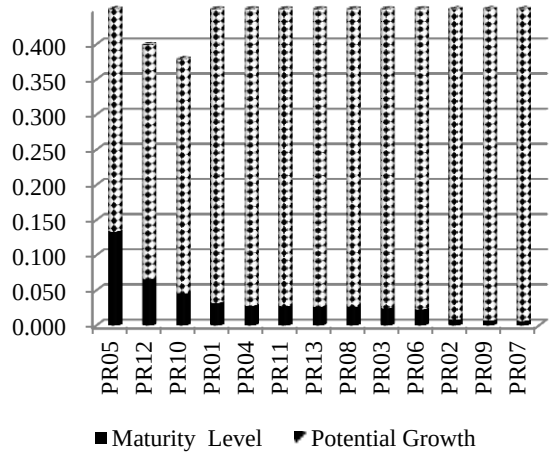

Figure 7(b) Maturity level and potential growth of procurement management (PR) key practices

5.2 Importance and Maturity Level of Key Practices Areas and Industry

The result of the experts' assessment of the importance of the six KPAs is shown in Figure 8(a). The result indicates a very traditional view of the industry i.e. 'cost is king' in construction projects and thus the KPA contributes to 28.01% of the total. This was followed by quality contributing 26.41%. The triple bottom line still rules the industry (except time was not assessed following the replication parameters of [19]. HR was at the bottom end contributing 7.89%. Perhaps the view was that 'everything done right or wrong surfaces in the triple bottom line'.

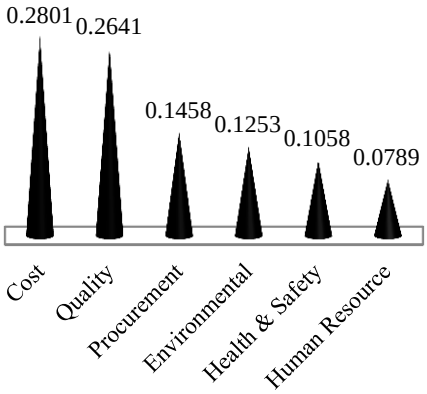

Figure 8(a) Weights (or importance) of the selected key practices of the CI

Figure 8(b) indicates that the top two KPAs are cost and quality management practices. They are also the least required to grow, at 45% and 46%. For engineering education this means more emphasis on these KPAs while sustaning the level of attention of the first two (cost and quality).

Figure 9 indicates Botswana construction industry maturity level being at 48.08% and a potential growth of 51.92%. This indicates the industry is in transition to maturity but has not yet reached the crucial mark of 66.66%. If the maturity is compared with that of Guyana (though cuatiously) of 53.61% with a growth potential of 46.39% [19], it indicates more effort is needed to nurture the former. However, as already noted the comparison must be done with great care because of the timing of the study (Guyana's study was done in before 2010) and the number of KPAs assesed i.e. Guyana was assesed with four while Botswana was six.

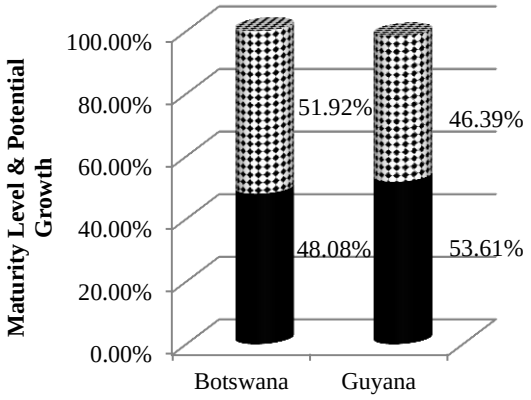

Figure 9: Botswana (and Guyana) Construction Industry Maturity Level
Source: [23,9]

5.3 Discussion

The results presented require reflecting on some of the potential limitations particularly in terms of the sampling, research design and collection of data. Convenience sampling was used to select participants and hence bias may have crept in as only those who were willing to take part in the study were selected and may not represent the industry. In addition, despite its superiority in decision making in relation to other methods the AHP is still a subjective scoring method to rate the maturity and weights of the KPs and KPAs. However, it was hoped that both threats to validity were minimised by selecting experts with immense experience of the experts and the averaging of their scores. In addition, the exclusion of the time and risk management practices is a misnomer as these are central KPAs to project delivery. Also the use of three threshold levels is not very sensitive in measuring the maturity of KPAs and KPs, for example, a four-tier maturity level (i. e. $\frac{0}{4}$, $\frac{2}{4}$, $\frac{3}{4}$ and $\frac{4}{4}$) might provide a better assessment.

Despite these limitations, the results of the study provide valuable insights. First, they have indicated that the construction industry is not mature (though not immature) and needs to grow substantially to deliver its mandate to facilitate sustained development. The results resonate very well with other studies (e.g.[6,5]) and media reports (e.g.[7,8, 33]) which often indicate that projects are not delivered according to expectations. This is due to the fact that all KPAs assessed are in a transitional state. Even the two most mature KPAs, cost and quality management, require substantial growth to elevate the industry's maturity. Procurement is one area that needs special attention because in many cases, other KPAs are affected by poor procurement practices [34,35]. Botswana being a semi-arid country needs to be environmentally sensitive during construction, especially in the preservation of water, fauna and flora. H&S is the 'bone' of construction and results have indicated that it has a low level of maturity. Both KPAs need substantial growth and the industry as a whole needs to craft strategies to improve the KPAs. HR received the lowest maturity, possibly indicating that the supply and quality of industry workers are inadequate. This being one of the objectives of the paper, the results provide valuable feedback to engineering education i.e. to focus on areas that will increase the skill level in all the other five KPAs (cost, quality, procurement, H&R and environment) at an appropriate level of training be it at undergraduate, post-graduate or as continuous professional development (CPD). The KPs which have the highest growth potential may provide the content of such training.

6 CONCLUSION

The study set out to measure the maturity level of the construction industry of Botswana using the CIM3 model as a possible means of providing feedback to engineering education. The level has been assessed to be at 48.1%, which according to the model is a transitional state to maturity (33.33%-66.67%). The findings implore tertiary and professional level educators to make special effort to increase the maturity of the KPs identified with low maturity through training, for example, how to prepare cash forecasts (CM9) to ensure effective cost management; and developing appropriate specifications and adhering to them during construction (QM4). Findings also highlight the need to sensitise industry operators on the requirement of upholding best practices and appropriate behavioural disposition, for example, prompt payment (CM7, budgeting for H&S (HS7) and environment protection (EM4). It should be borne in mind that engineers are only one set of the professionals who work in the construction industry. The road to maturity requires all professionals (including architects and quantity surveyors) to be at the same level of proficiency. Therefore, some of the findings apply to their practices. This multi-prolonged approach will enable the industry to achieve potential growth and reduce the identified deficit of 51.92%. A further study is being conducted to increase the KPAs to eight (to include time and risk) in order to assess the industry on a wider spectrum of KPAs and to use a more sensitive assessment scale such as the four-tier maturity level.

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Student Voices regarding Practical Instruction in a Solar Energy Course indicates Student Satisfaction

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***Abstract*- Within higher education, student voices or perceptions are useful in measuring effective instruction and are important to evaluate the nature and quality of educational interventions. Student voices are often considered in determining whether student academic satisfaction exists with regard to the quality of engineering education being offered. The question thus arises "What does student voices say regarding practical instruction offered in a Solar Energy course at the Central University of Technology in South Africa". Research has shown that voices of undergraduate engineering students indicated that they really enjoy practical work scheduled in a laboratory, thereby indicating a measure of student satisfaction. However, this was reported on only for students in an electronic communications course, with fewer results published for undergraduate engineering students in other disciplines at a university of technology. The purpose of this paper is to consider student voices regarding practical instruction offered in a Solar Energy course at a university of technology. An exploratory case study is employed along with descriptive statistics for the quantitative data relating to the student voices. An electronic response system was used in a classroom environment to listen to student voices relating to the practical work done in the laboratory. These student voices did confirm that many of the students felt that the practical work was beneficial, relevant and practical in helping them apply new knowledge in solving engineering problems, resulting in a measure of student satisfaction. This has the potential to result in the retention of the best and brightest students from among these participants for future postgraduate studies which will most likely involve more intensive laboratory work!**

Keywords: Solar energy, student voices, learning outcomes, graduate attributes

I. INTRODUCTION AND RATIONALE

"Your most unhappy customers are your greatest source of learning" [1]. These words, by Bill Gates, illustrate the value of feedback which can be used to rectify deficiencies or improve products or services. Within higher education, student voices or perceptions are useful in measuring effective instruction [2] and are important to evaluate the nature and quality of educational interventions [3]. Student voices are often considered in determining whether student academic satisfaction exists with regard to the quality of engineering education being offered. In fact, a key dispositional factor, emerging from the literature that serves to enhance or inhibit student retention is their satisfaction with their course experience [4-7].

Student retention is defined as the ability of an institution to retain a student from admission through graduation [8]. However, at the operational level, student retention includes continuing further studies at the same university [9]. This suggests that undergraduate students who perceive their current educational experience to be satisfying will most likely continue their postgraduate studies at the same institute. In fact, laboratory work, or hands-on activities, can improve student understanding, providing high student satisfaction with the learning experience [10, 11].

Undergraduate engineering students at the Central University of Technology (CUT) have the choice to enrol for a National Diploma or Certificate in a number of different engineering disciplines which include both theoretical and practical work. This affords students the opportunity to demonstrate vital graduate attributes such as problem-solving, technical competence, teamwork and technological literacy. Problem-solving requires students to use prior knowledge to find a solution to a problem [12] while a technologically literate person must have a certain amount of basic knowledge about technology [13]. Technical competence refers to the application of knowledge and skill in the completion of a task [14] while teamwork points to the ability of students to work effectively in a group [15]. These attributes may be assessed by means of practical assignments scheduled in a laboratory.

Research has shown that many undergraduate engineering students really enjoy practical work scheduled in a laboratory [16-18], thereby indicating a measure of student satisfaction. However, this was reported on only for students in an electronic communications course, with fewer results published for undergraduate engineering students in other disciplines at a university of technology (UoT). The following research questions, therefore, arise: What are the perceptions of undergraduate students about practical work done in a Solar Energy course? Do they find it enjoyable, challenging, relevant and constructive?

The purpose of this paper is to consider student voices regarding practical instruction offered in a Solar Energy

course at CUT. Listening to student voices on aspects relating to their educational experiences is an inexpensive, simple and efficient research method to gather information [8] that allows different aspects of the learning environment to be assessed by the individual student [9]. It must though be noted that these voices are only personal assessments [19]. However, students can validly comment on the quality of teaching as they directly experience it [20], as it constitutes a mental representation of learning activities that affect student's conscious and unconscious choices in the learning environment [21].

This paper will firstly highlight the importance of student voices. The context of the study will then be explained, followed by the methodology, results and conclusions.

II. THE IMPORTANCE OF STUDENT VOICES

By purposefully listening [22] to students and by treating them with the appropriate respect [23], educators are empowering students [24] to contribute to their learning experience. If taken into account, student voices may contribute to the development of a module [25] via the efforts of their lecturer. Educators, on the other hand, can gain valuable insight into different aspects of their teaching methods and materials used from a student's perspective [26].

One of the challenges of listening to student voices may include creating an environment where students can make a difference [27]. Students must feel that what they say is taken seriously [28] and that it will be taken into account concerning their learning experience. It may further be challenging to engage in dialogue with students and respond in ways that validate the students input and honour the educators pedagogical commitments [29]. Study's where student voices were used by researchers include:

- An investigation into how specific influences were perceived by Mäori students [30].
- Identifying the best practices for civic education in 22 schools in Philadelphia [31].
- Choosing between online and face-to-face courses at the Teachers College at Columbia University [32].
- Improving the quality of course evaluations at the Colorado School of Mines [33].

These are just a few of many cases where researchers used student voices to try and improve the learning experiences. In fact, a search for the words "student voices" on Google Scholar returns more than 13 000 hits.

III. RESEARCH CONTEXT

The Department of Electrical, Electronic and Computer Engineering at CUT offers courses in electrical and computer engineering. These courses deal with the study and application of electricity, electronics, electrostatics and electromagnetism. Sub-studies include power electronics, control systems, signal processing and telecommunications. Undergraduate electrical engineering students at CUT have the choice to enrol for either a National Diploma or a Higher Certificate.

Students have to obtain a minimum of 360 credits for the National Diploma, which is a NQF (National Qualifications Framework) level 6 qualification. The majority of modules in this programme have a credit value of 10 (students should dedicate at least 100 notional hours to each module), requiring students to register for approximately six modules per semester (13 weeks in duration). Four semesters (or two full academic years) are usually required to obtain all the credits with a third year devoted to compulsory work integrated learning where the student will work in the industry and obtain 60 credits per semester.

The Higher Certificate in Renewable Energy Technologies (HSRET) is the first pre-graduate course in renewable energy that was approved by the South African Qualification Authority (SAQA). This certificate was designed for those individuals that want to enter the renewable energy field as technicians, thereby enabling students to prove that they have achieved a basic knowledge of the fundamental principles of the application, design, installation and operation of Photovoltaic (PV), Solar and Small Wind energy systems. A total of 120 credits is required for the HSRET and is currently an NQF level 5 certificate. This certificate requires a full year of instruction [34] where one of the required modules is termed Solar Energy Systems II. This module forms the basis for this research paper (its structure is shown in Table 1.)

Table 1: Module structure and assessments of Solar Energy Systems II

Module	**Solar Energy Systems II**	**Structure**
Main sections in syllabus (theory sections)	1. Introduction to solar energy 2. Solar system configurations 3. Components of a Solar Electric System 4. Design of photovoltaic systems 5. DC and AC measurements on PV systems	5 learning outcomes 4 learning outcomes 4 learning outcomes 5 learning outcomes 2 learning outcomes
Formative assessments	Two written classroom tests where the first test contributes 25%, and the second test 40% to the total course mark	• Test 1 includes 25 marks from section 1 and 2 • Test 2 includes 50 marks from section 1 to 5
Practical instruction	5 x practical experiments which contribute 35% to the total course mark	Each practical is linked to a theory section
Summative assessment	1 x closed book examination The student's final mark comprises 40% of the course mark and 60% of the examination mark	20 marks per theory section covered in the examination

Students are required to complete two written class tests that contributed 25% and 40% towards their total course mark. The other 35% of the course mark is derived from the practical instruction which is completed in a laboratory using an innovative jig and accompanying software that was developed by the authors [35]. Students are given a final summative written assessment (examination) at the end of the semester, which covers both the theoretical and practical instruction. The student's final mark is calculated using 40% of the course mark and 60% of the examination mark. Student voices regarding the practical instruction offered in this certificate were obtained to determine if students were satisfied with the learning experience.

IV. RESEARCH METHODOLOGY

An exploratory case study is employed along with descriptive statistics for the quantitative data relating to the student voices. According to Yin [36], an exploratory case study is appropriate for preliminary inquiries and is ideal for analysing what is common and different across cases that share some key criteria. The analysis of common and different student voices is sought regarding the same criteria, namely benefits, relevance and practicality of the practical work done in a laboratory. Descriptive statistics are used as the results are interpreted by individual African engineering students enrolled at CUT.

Quantitative analysis is important as it brings a methodical approach to the decision-making process, given that qualitative factors such as "gut feel" may make decisions biased and less than rational [37]. The target population was restricted to 33 African engineering students enrolled for Solar Energy Systems II during 2014 and 2015. The sample size is small as these were the first students to enrol for this new Certificate. An electronic response system was used in a classroom environment at the end of the semester to listen to student voices relating to the practical work done in the laboratory and its submission via a learning management system[38]. These voices were heard by posting specific questions relating to student satisfaction of the learning experience which were based on previous research [39, 40].

Student voices are considered with regard to the perceived benefits of the practical instruction. This is especially considered with regard to problem solving skills and whether the practical instruction was relevant to the theory presented in the classroom. The practicality of the work was also ascertained by asking students to what degree they engaged with design principles for standalone and grid connected solar engineering systems. Positive responses to the perceived benefits, relevance, and practicality of the practical instruction are viewed as indicators of student satisfaction that may lead to improved student retention.

V. RESULTS

Results of the student voices regarding the practical instruction which they received are divided into four sections, namely benefits, relevance, practicality and suggestions. Answers from students regarding benefits (Figure 1), relevance (Figure 2) and practicality (Figure 3) are presented on a Likert scale that range from strongly agree to strongly disagree. Students were also given the opportunity to make suggestions regarding the practical work done in the module (see Figure 4).

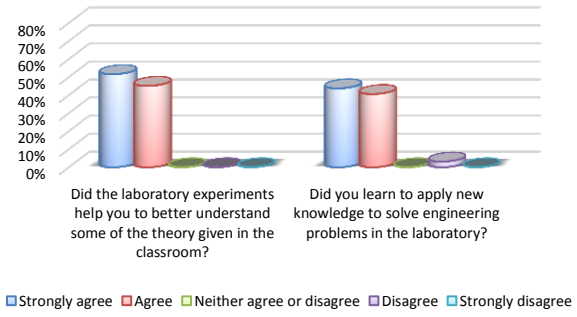

Figure 1: Student voices regarding the benefits of the practical work

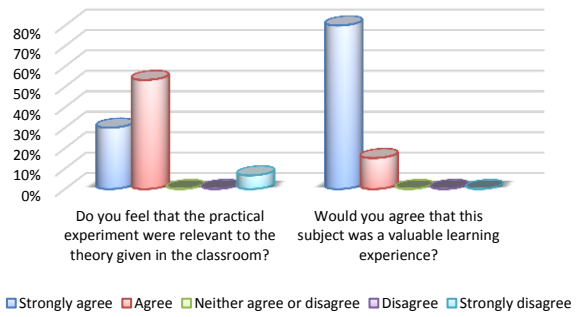

Figure 2: Student voices regarding the relevance of the practical work

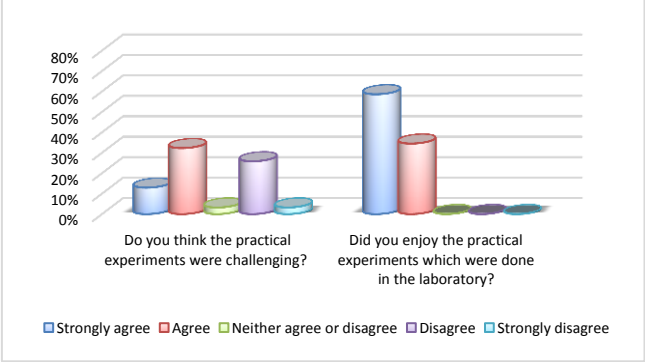

Figure 3: Student voices regarding the practicality of the practical work

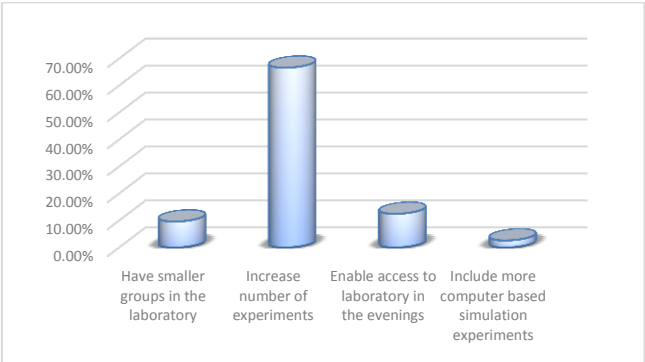

Figure 4: Student voices regarding suggestions for the practical work

VI. Discussion of Results

Figure 1 indicates that 96% (strongly agree and agree) of the students agreed that the practical work helped them to better understand the theory in Solar Energy Systems II. In response to the question regarding the application of new knowledge, 84% indicated that they learned how to apply new knowledge in solving engineering problems (see Figure 1). These results tend to suggest that a measure of student satisfaction was achieved in the practical work, which may enhance student retention [4-7].

Figure 2 highlights that 93% of the students agreed that the practical work was relevant to the theory discussed in the classroom. A further 97% indicated that the module was a valuable learning experience. This suggests that the practical work is aligned to the theoretical work, adhering to the principles of constructive alignment [41].

Figure 3 shows that 34% of the students agreed that the practical work was challenging, while 31% felt that they were not challenging. These opposite responses may suggest that there was a fair degree of difficulty in completing the practical work. In response to the question whether the students enjoyed the practical work, 93% of the students responded affirmatively. These results tend to suggest that a measure of student satisfaction was achieved with regard to the practical work, thereby implying that they will be more motivated to complete their studies [42].

Students were also asked to make recommendations about the practical work done in the Solar Energy Laboratory (Figure 4). Although the practical groups consisted of only five members, 10% of the students felt that the groups should be smaller. The results further show that 67% of the students felt that more practical work was necessary. 12% indicated that more laboratory time should be allocated in the evening. Time-on-task helps students to take ownership of their knowledge, creating linkages and relationships within their own knowledge structures [43]. Results also indicated that 3% of the students would prefer more computer-based simulations, which is similar to results obtained in Australia where a survey was conducted regarding the usefulness of remotely accessible laboratories [44].

VII. Conclusions

The purpose of this paper was to consider student voices regarding practical instruction offered in a Solar Energy course at a UoT. Responses indicate that practical work done in this laboratory has the potential to enable students to develop the right graduate attributes of problem-solving, technical competence, teamwork, and technological literacy.

In response to a question regarding the application of new knowledge, 84% of the students indicated that they learned how to apply new knowledge in solving engineering problems (graduate attribute of problem-solving and technical competence). 93% of the students agreed that the practical instruction was relevant to the theory discussed in the classroom and that it was enjoyable (bear in mind that it was scheduled in groups which means that the graduate attribute of teamwork is addressed). 97% of the students indicated that the module was a valuable learning experience as they engaged with different technologies (graduate attribute of technological literacy).

These student voices confirm that many of the students felt that the practical work was beneficial, relevant and practical in helping them apply new knowledge in solving engineering problems, resulting in a measure of student satisfaction. This has the potential to result in the retention of the best and brightest students from among these participants for future postgraduate studies which will most likely involve more intensive laboratory work!

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Outcome-based Module for Continuous Assessments in Engineering Education: Case Study Department of Electrical and Electronic Engineering Science at the University of Johannesburg

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***Abstract*—A big challenge for all engineering universities is the high quality of their graduated students to match the professional engineering qualities that industry need. In South Africa, the Engineering council of South Africa (ECSA) always asked for proof of evidence that students have demonstrated their capabilities to pass all the knowledge areas in each one of their modules in their engineering degree curriculum. The department of electrical and electronic engineering science at the University of Johannesburg has introduced a new continuous assessment framework based on outcomes in the offered modules. This framework allows for a deeper assessment of knowledge. Advantages and disadvantages of this new assessment scheme are discussed in this paper as well as the solutions proposed to make it a flexible and successful for all students.**

Keywords—Education, Engineering, Assessments, Throughput, Module.

I. INTRODUCTION

Since 2011 the Department of Electrical and Electronic Engineering Science at the University of Johannesburg moved to a continuous assessment framework based on outcomes in the offered modules. This framework allows for a deeper assessment of knowledge.

The department changed its assessment strategy from the traditional summative assessment model consisting of semester tests and an examination to a more fine grained outcomes based continuous assessment model [1]. Each module or course was divided into a set of outcomes which encompassed key knowledge areas in the module. During the course of the semester three smaller formative assessments were designed and implemented for each outcome.

To pass a module the student would have to pass each outcome in that module separately. Although this process allowed us to ensure that students had demonstrated their grasp of each knowledge area in that module and that students could not slip through the module on an average mark by mastering one section of the work and not another the process revealed the heavy load placed on the students shoulders. The solution for this will be discussed in the coming sections and we will show how we could adjust this assessment scheme without changing its core and main goal.

During 2015 academic year, I have had the opportunity to lecture three modules for my third year students, I have lectured Signals and Systems (SST3A11), Digital Signal Processing (SIG3B01) and Telecommunications (TEL3B01) modules, where students study analog signals and systems, digital signals and systems and analog modulations respectively.

Since 2011 until first semester of 2015, I used to follow the classic scheme of assessment suggested by the department, which heavily burdened both students and lecturers. This was noticed during both students' preparations for their tests and the little time lecturers had to provide more assistance to their students due to the overwhelming administration responsibilities generated by the new assessments system. As a result of this and despite the extra effort I usually do during my lectures, the throughput rates for my modules are always 65% to 80%. Therefore, I decided to present a new assessment scheme to improve my throughput rates, save time for my students and myself and to improve the quality of my lecturing and skills. Very good results have been achieved and the throughput rates scored high values even 100% as will be explained in details in the coming sections.

The paper is organized as follows. A coverage of the assessments methods that have been used during the academic year of 2015 is presented in Section II. Finally, a conclusion summarizing the achievements which led to the improvement of the throughput rates is presented in Section III.

II. ASSESSMENTS

The department of Electrical and Electronic Engineering Science changed its assessment strategy from the traditional summative assessment model consisting of semester tests and an exam to a more fine grained outcomes based continuous assessment model. Each module was divided into a set of outcomes which encompass key knowledge areas in the module and which could also be seen as a chapter with a common theme. The system is considered to be efficient in terms of knowledge acquisition and serves as a guarantee to the

	Assessments	Kind of Assessment	Assessment Details	Assessment Weight	Outcome Weight
Outcome A					**25%**
	Assessment 1	Writing assessment	Problem Solving and Derivation	70% Exemption 0.7Max1+0.3Max2	
	Assessment 2	Practical	Problem Solving and Derivation		
	Assessment 3	Writing assessment	Problem Solving and Derivation		
Outcome B					**25%**
	Assessment 1	Writing assessment	Problem Solving and Derivation	70% Exemption 0.7Max1+0.3Max2	
	Assessment 2	Practical	Problem Solving and Derivation		
	Assessment 3	Writing assessment	Problem Solving and Derivation		
Outcome C					**25%**
	Assessment 1	Writing assessment	Problem Solving and Derivation	70% Exemption 0.7Max1+0.3Max2	
	Assessment 2	Practical	Problem Solving and Derivation		
	Assessment 3	Writing assessment	Problem Solving and Derivation		
Outcome D					**25%**
Practicals: Reports and Matlab programming					
Final Mark					
	Average (Outcome A + Outcome B + Outcome C + Outcome D)				**100%**

Table 1: Structure for Assessments used for SST3A11 Module

	Assessments	Kind of Assessment	Assessment Details	Assessment Weight	Outcome Weight
Outcome A					**33%**
	Assessment 1	Writing assessment	Multiple-Choice + Theory	30%	
	Assessment 2	Practical	Report + Demonstration	30%	
	Assessment 3	Writing assessment	Problem Solving and Derivation	40%	
Outcome B					**33%**
	Assessment 1	Writing assessment	Multiple-Choice + Theory	30%	
	Assessment 2	Practical	Report + Demonstration	30%	
	Assessment 3	Writing assessment	Problem Solving and Derivation	40%	
Outcome C					**33%**
	Assessment 1	Writing assessment	Multiple-Choice + Theory	30%	
	Assessment 2	Practical	Report + Demonstration	30%	
	Assessment 3	Writing assessment	Problem Solving and Derivation	40%	
Final Mark					
	Average (Outcome A + Outcome B + Outcome C)				**100%**

Table 2: Structure for Assessments used for SIG3B01 Module

	Assessments	Kind of Assessment	Assessment Details	Assessment Weight	Outcome Weight
Outcome A					**35%**
	Assessment 1	Test	Quiz	20%	
	Assessment 2	Test	Multiple-Choice + Theory	30%	
	Assessment 3	Test	Problem Solving and Derivation	50%	
Outcome B					**35%**
	Assessment 1	Test	Quiz	20%	
	Assessment 2	Test	Multiple-Choice + Theory	30%	
	Assessment 3	Test	Problem Solving and Derivation	50%	
Practical					**30%**
	Practical	**Project**	Report	30%	
			Hardware implementation	70%	
Final Mark					
	0.35*Outcome A + 0.35*Outcome B + 0.3* Practical				**100%**

Table 3: Structure for Assessments used for TEL3B01 Module

industry, demonstrating our students' capabilities to pass all the knowledge areas in each module.

Students have three assessment opportunities to pass the outcome. During the course of the semester three smaller formative assessments were given for each out-come. To pass an outcome a student has to achieve a 50% mark in two of the assessment opportunities or a 70% mark in one of the opportunities. The philosophy was that the student could fail one opportunity and use the experience gained from that opportunity to pass subsequent assessments. The 70% threshold was instituted to allow students that have mastered a given outcomes knowledge to be able to demonstrate their knowledge once and then be able to focus on the remaining work [1].

Personally I started using the outcome-based assessments since 2011. In 2015 I had the opportunity to lecture three courses to third-year students, Signal and Systems (SST3A11) in the first semester and two other modules in the second semester, Digital Signal Processing (SIG3B01) and Telecommunications (TEL3B01).

After almost five years of using the outcome-based assessments, I decided in 2015 to evaluate this assessment scheme and to develop another assessment scheme using different assessments styles. This was to avoid the heavy load caused by the outcome-based assessment and the type of questions offered to students.

In my first semester course, Signal and Systems, I applied the departmental assessment module, considering the practicals as an outcome on their own. The scheme of calculating my students' marks is depicted in the table shown in Table 1. It can be seen that students have three outcomes and practicals, where three assessment opportunities are offered to students with same way and type of questions, the problem solving and derivation.

In the second semester for my SIG3B01 module, I applied a different assessment scheme from the one used with SST3A11 module. In this case I retained the three assessment opportunities to meet the ECSA requirements but this time I considered the practicals as one of the assessments. This reason for dropping the number of assessments was that they usually create a heavy load on students and affect their results and therefore the throughput rate. Another modification was to give different varieties of assessments that did not focus only on one type of assessment, as in the previous scheme, as problem solving and derivation. I introduced a multiple-choice type of assessment to cater for all different students' choices. This choice of assessment was fair for students who are not comfortable with problem solving as the only type of assessment. Since different types of questions require different time allocations, I adjusted the percentage of each assessment mark to the final mark. The final students' marks are calculated as shown in Table 2.

In the case of TEL3B01 module I kept the same assessment style for SIG3B01 but moved the practicals on their own - not as in the case of SST3A11 - but to the form of a small project that contributed a certain percentage to the final mark of the module. The idea behind this was to give a chance to students to do a separate project and submit it at the end of the semester and to take advantage of the practical allocated time to do revision or any kind of homework. As a result of this new model and to be consistent with the ECSA's assessment requirement, a third assessment was required. Thus, I introduced the quiz assessment which carried a lower percentage to accommodate the rest of assessment types. The final students' marks are calculated as shown in Table 3.

A survey was conducted among my students to gauge their preferences and how comfortable they were with each of the assessment types. I preferred not to rely on the results only; I wanted them to express their views on this matter and to assist

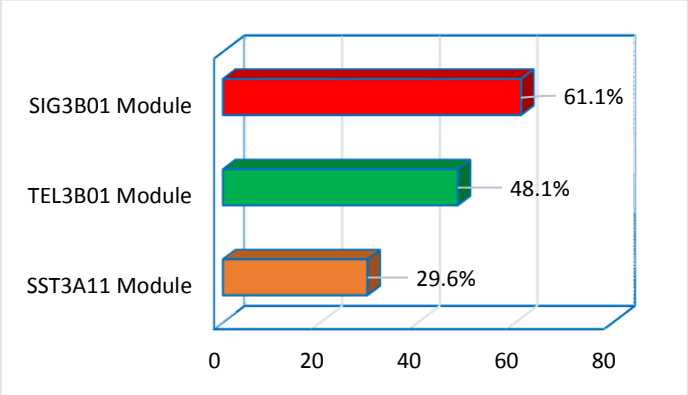

Figure 1: Students Evaluation of Modules Assessments Schemes

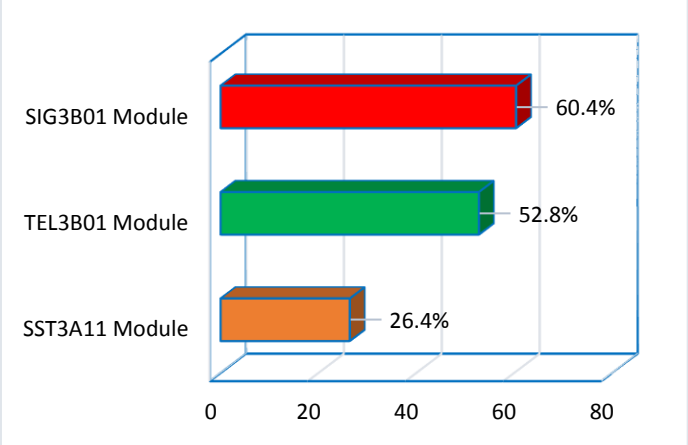

Figure 2: Students Preferences for the Assessments Schemes

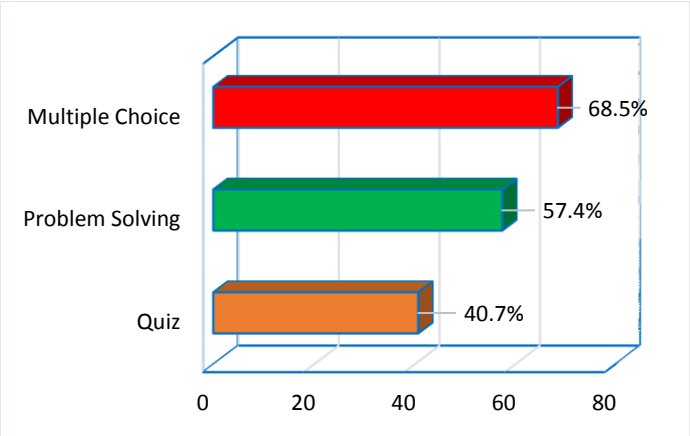

Figure 3: Students Preferences for the Kinds of Assessments

me in improving the proposed assessment schemes. Figures 1, 2 and 3 provide information on students choosing the right assessment scheme for their benefits and the type of scheme that helped improving their marks. It is clear that from Fig. 1, that students prefer the assessments tool used for SIG3B01 as the scheme that suits better the outcomes based assessment approach. From Fig. 2, it is clear that the assessment tool used with SIG3B01 is the one they feel more comfortable with.

Fig. 3 shows that multiple-choice assessment is the best choice for students which means that this assessment tool help them the most in getting better marks.

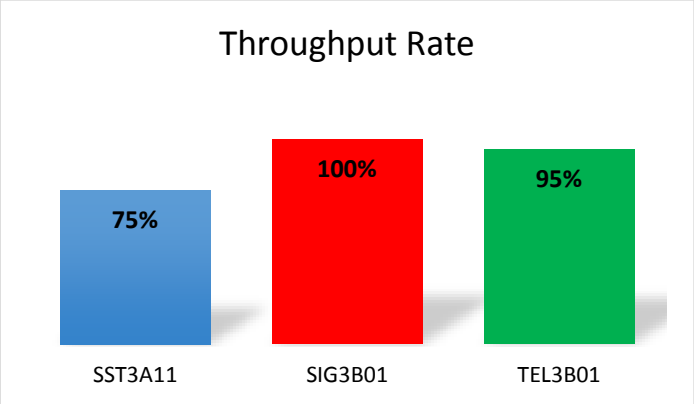

Figure 4: Throughput Rates of Different Modules

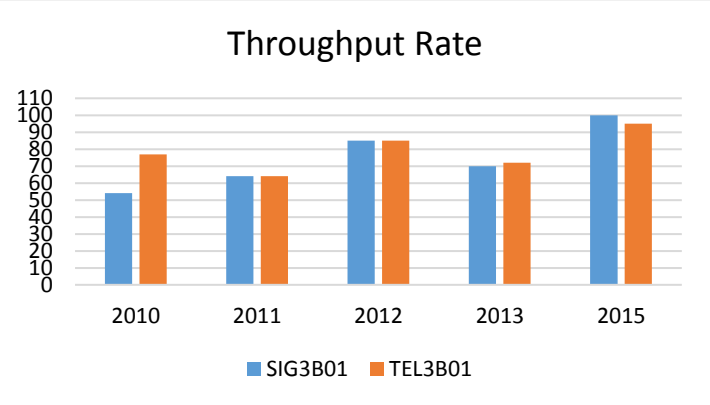

Figure 5: Throughput Rates from 2010 until 2015

III. CONCLUSION

It is clear from the results presented in the previous results that outcome-based module for continuous assessments should have flexible assessments type as it was proved students prefer multiple-choice assessment and the use of practical as one of the three assessments. This helped off loading students with the number of assessments from each module.

The comparative results between my modules SST3A11, SIG3B01 and TEL3B01 lectured in 2015, show the proposed assessments schemes in 2015 is much better in improving the throughput of module than the classic assessment scheme used in previous years as presented in Figures 4 and 5.

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A review of the Information System Models for Technology Acceptance

Boniswa Mafunda, Arthur J. Swart, Aaron Bere

***Abstract*- The words "acceptance" and "behaviour" have been used interchangeably. The acceptance of any form of technology is determined by the behaviour of the individual towards that technology. Extensive research has been carried out on factors that influence human behaviour. This includes research in mathematics, philosophy, anthropology, information systems theories and many more. In the field of Information Technology and Information systems, there are models that have been developed in an attempt to try and understand technology acceptance. The aim of this paper is to review 6 unique Information Systems models of acceptance (Diffusion of Innovations, Theory of Reasoned Action, Theory of Planned Behaviour, Technology Acceptance Model, Task Technology fit and Unified Theory of Acceptance and use of Technology). The paper defines each of the models, providing past applications and recommending future applications within the context of a university of technology. The aim of this review is to help create awareness among fellow academics about the various acceptance models and their possible usage.**

***Keywords*- Diffusion of Innovations, Theory of Reasoned Action, Theory of Planned Behaviour, Technology Acceptance Model, Task Technology Fit, Unified Theory of Acceptance and use of Technology,**

I. INTRODUCTION

The acceptance of a technology, or lack thereof, is determined by an individual's behaviour or attitude towards the technology [1]. The lack of user acceptance is a barrier to the success of new technology innovations [1]. In a university context, the aim of a technology is to improve performance. When performance is improved, technology adoption is attained. In a pragmatic viewpoint, understanding the factors of IT use ought to guarantee effective deployment of IT resources within an organization [2].

According to Taylor and Todd [2] a diversity of perspectives of theoretical research has provided an improved understanding of the factors that affect technology use. This theoretic research includes intention-based models which use behavioural intention to predict the use of technology.

In this paper, 6 technology acceptance models are reviewed. The paper reports on the Diffusion of Innovations (DIO), Theory of Reasoned Action (TRA), Theory of Planned behaviour (TPB), Technology Acceptance Model (TAM), Task Technology Fit (TTF) and the Unified Theory of Acceptance and Use of Technology (UTAUT). Each of the models is introduced in the form of a brief history, what the model entails, where it has been used and where it can be used in the Central University of Technology (CUT) context. Recommendations as to how these technologies may be used at a university of technology may heighten academic awareness of these technologies. The paper then ends with a conclusion.

II. DIFFUSION OF INNOVATIONS

The Diffusion of Innovations (DIO) theory was developed in the United States by Everett Rogers, a rural sociologist and professor of communication studies in 1962 [3]. The DIO theory originates from the "German-Australian and the British schools of diffusionism in anthropology". Members of these schools noted that most variations in society result from the outline of innovations from supplementary societies. French sociologists further suggested incorporating the S-shaped diffusion curve and the role of estimation leaders in the progression of "imitation" [4].

Greenhalgh, et al. [5] define the DIO theory as a theory that seeks to explain how technology spreads through culture. Furthermore, it seeks to explain the rate at which new technology and ideas are adopted [5]. According to Wejnert [6], the DIO theory denotes a range of intellectual ideas and notions, methodological information, and definite practises in a social system. It clarifies where the range indicates movement from a basis to an adopter, usually through communication and impact.

The DIO model is depicted in figure 1. The DIO theory, according to Rogers (1976), is a procedure by which an origination is interconnected. The interconnection is over certain canals during a specific period between the affiliates of the social order system. Through succeeding clusters of consumers accepting the new technology (presented in blue in figure 1), its market share (yellow) will eventually reach the saturation level [4]. Rogers [4] declares that in mathematics terminology, the yellow curve is called the logistic. The curve is divided according to sections of adopters

The DIO was initially used in the adoption of organic agriculture [7]. It was applied in a study that reviewed a large number of studies in organic farming. The study was carried out in several countries over a period of about 20 years.

The DIO was applied in health studies. The study summarised an extensive literature review regarding the spread and sustainability of health service delivery [5]. It was also applied in social networks as a basis for adopter categorisation instead of solely relying on the system-level analysis [8].

At the CUT, the DIO can be used to evaluate e-thuto (Blackboard) system. Blackboard is a culture amoung most universities. The DIO could be used to evaluate the use of blackboard amoung lectures. The results may explain the rate at which Blackboard is adopted and reveal whether it is used to its full functionality.

III. THEORY OF REASONED ACTION

The Theory of Reasoned Action (TRA) was proposed by Martin Fishbein and Icek Azjen in 1975. It was a derivative of a previous study that began as an attitude theory [9]. According to Vallerand, et al. [9],

the TRA is a popular model in the domain of social psychology.

The theory proposes that an individual's behavioural intention is subjected to the individual's attitude concerning behaviour and subjective norms [10]. These researchers added that, if an individual anticipates an action, then it is probable that the individual will engage with the action.
The TRA consists of three general constructs: Behavioural intention, Attitude, and Subjective norm. Behavioural intention measures one's relative intention to execute an action or specific behaviour. Attitude entails the beliefs about the shortcomings of executing the behaviour multiplied by one's evaluation of the shortcomings [10]. Subjective norm is the perceived societal pressure cause by one's perception and refers to the social pressure a person feels in carrying out or not carrying out a specific behaviour [10]. The model has its constructs depicted in figure 2. According to figure 2, an individual's behavioural intention is influenced by the individual's attitude and subjective norm. Once behavioural intention exists, then the individual will perform the behaviour.

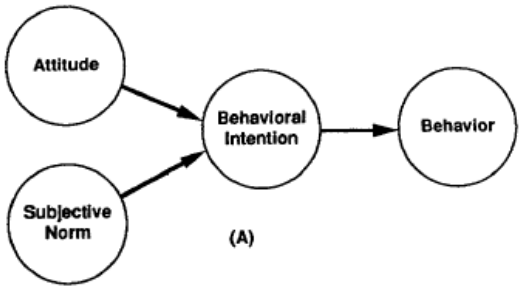

Figure 2: The Path Model for Theory of Reasoned Action [10]

The TRA was applied in commerce to test its ability to predict consumer online grocery buying intention [11]. It was also applied in a study that evaluated the use of coupons by consumers [12].
In the health industry, the TRA was applied as framework for understanding and AIDS related behaviours [13]. In IT, the TRA was applied in a study that investigated the adoption of IT by end-users. The TRA was integrated with the DIO and the model indicated good support that it can be used for understanding the utilisation of IT [14].

At CUT, this model may be applied in investigating the use of the solar panel USB chargers at the Engineering and IT faculty. The TRA can be applied in investigating the behavioural intention of students towards the solar panel USB chargers. Applying the TRA may reveal an individual's attitude concerning behaviour and subjective norms.

IV. THEORY OF PLANNED BEHAVIOUR

According to Francis, et al. [15] the theory of planned behaviour (TPB) was developed in 1988 by Icek Azjen to improve the predictive power of the TRA. The TPB connects human principles and behaviour and is devised from the psychology subsidy; it also lengthens the limiting conditions of wholesome volition stated in the TRA [16].

Madden, et al. [16] proclaimed that the TPB comprises beliefs concerning the proprietorship of mandatory resources and prospects for execution of a given behaviour. The theory states that one's attitude towards behaviour, subjective norm and perceived behavioural control, shape an individual's behavioural intention and behaviours [17].

According to the theory, human behaviour is guided by two types of concerns: behavioural beliefs and normative beliefs [16]. Behavioural beliefs relate to the probable results of the behaviour and the assessment of these results. Normative beliefs concern the normative anticipations of others and the drive to conform to these anticipations. According to Azjen [18], attitude concerning the behaviour, subjective norm, and perceived behavioural control result in the realisation of behavioural intention. In conclusion, given an adequate amount of definite mechanism over the behaviour, individuals are anticipated to perform their intent when the occasion arises. Figure 3 represents the TPB where attitude, subjective norm and perceived behavioural control will predict the intention to perform a behaviour. Intentions are the predecessors of behaviour. The constructs of this model reflect psychological constructs that have a distinctive implication for the theory [9].

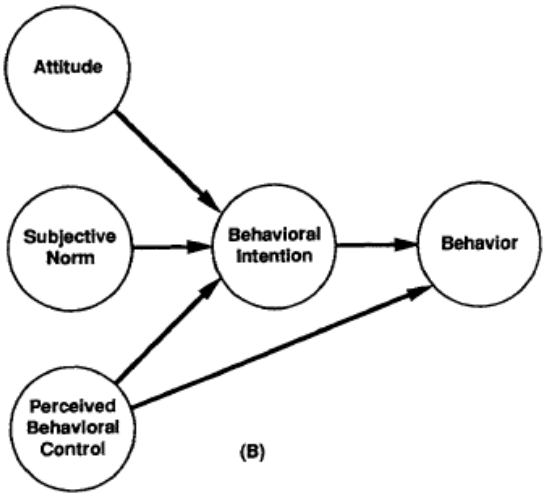

Figure 3: The Path Model for Planned Behaviour [10]

The TPB was applied in the Psychology field in a study that examined the role of self-identity and social identity constructs on intention behaviour. The study was concerned with the prediction of intention to engage in household recycling and reported cycling behaviour [19].
The TRA was applied in the Entrepreneurial field [20]. The study investigated the behavioural intention of entrepreneurs towards entrepreneurship. In Sports Management, the TRA was applied in studies that determined the behaviour and role of sports exercises and better understanding the consumers' intention in attending a sports event [21-23].
At the CUT, the TPB can be applied to first year computer literacy students. It can also be used to evaluate the behaviour of lectures towards the use of Clickers technology

in their classes. Applying the TRA in this context may reveal the lecture's normative beliefs. It may also give insight to the normative beliefs of lectures.

V. TECHNOLOGY ACCEPTANCE MODEL

The Technology Acceptance Model (TAM) is the most prominent extensions of Azjen and Fishbein's TRA which was developed by Fred Davis in 1986. Surendran [24] ascertains that the TAM is one of the theories that has been based on TRA and has been used to explain an individuals' acceptance behaviour. Teo [25] argues that it is one of the utmost prominent additions of Ajzen and Fishbein's TRA. According to Kashi and Zheng [26], the TAM has substituted several of TRA's attitude measures with the two technology acceptance measures (ease of use, and usefulness). It suggests that apparent usefulness and apparent comfort of use include a person's intention to make use of a system with "intention to use" serving as an intermediary of real system use [27]. The TAM incorporates two fundamental constructs, namely PEOU and PU [28]. Park [28] declares that the core apparatuses essential to PEOU are design and features of a technology while the main understanding of PU is exertion-decreasing. According to Al- Adwan, et al. [29], the TAM is acknowledged as one of the well-known models related to technology acceptance and use. It has presented great potential in unfolding and predicting the actions of users of a technology [29]

According to Gómez, et al. [30], the TAM is a model that simulates how users come to adopt and use a technology. The TAM is further designed for demonstrating user approval of information systems [31]. Wu and Ke [32] declare that the TAM is a model that can efficiently describe user behaviours relative to new technologies. Wu and Ke [32] also suggested that the TAM is an adoption theory, meaning it emphasises that when an individual decides to perform an action, then they will do it without hesitation.

Davis [33] states that performance achievements are often disillusioned by user's reluctance to acceptance and use of an existing system. According to Davis [33], people have a habit of using or not using a technology to the magnitude they trust it will be of assistance to them in better performing their tasks. This variable is referred to as PU. Even if prospective users have faith that a given technology is worthwhile, they may possibly also trust that the technology is too difficult to use. Performance reimbursement usages are thereby determined by the exertion of using a technology [33]. Furthermore PU is hypothesised to be subjective to PEOU and is linked to the other four constructs of the TAM.

According to Nath, et al. [34], the TAM recognises PU and PEU as influential in Attitude towards and the Intention to Use a technology. It regards them as the most important determinants of Actual Use (Davis et al., 1989. Figure 4 presents the original TAM, where external variables do influence PU and PEOU [35]. Collerette, et al. [35] defines the external variables as the system's characteristics. PU and PEOU determine the individual's attitude towards use and in turn influence intention to use.

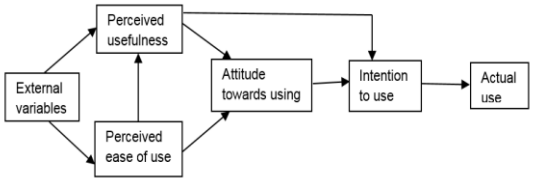

Figure 4: Technology Acceptance Model [33]

In education, especially for electronic learning (e-learning) and mobile learning (m-learning), the TAM has been vastly applied [30, 36-38]. It was applied in study that evaluated the acceptance of e-learning systems by students.

The TAM has been evaluated in corporate companies [26, 34, 38]. The TAM was applied in a study that examined the attitudes of employees and their acceptance of e-learning systems in their organisations.

In the field of management studies, the TAM has been widely used [39-41]. The TAM was applied in a study that investigated PU and usage intention in terms of influence [41]. This was for the purpose of evaluating four longitudinal studies in management.

The IT department at the CUT has introduced the use of Barcoded scanners for student attendance in the Digital Literacy classes. These Barcode scanners are only limited to the Digital Literacy classes. The TAM can be applied in evaluating the acceptance and adoption of these devices.

VI. TASK TECHNOLOGY FIT

The Task Technology Fit (TTF) theory was developed by Goodhue and Thompson in 1995 [42]. This theory is a linkage of models from two complementary streams of research (user attitudes as predictors of utilisation and task-technology fit as a predictor of performance). Goodhue and Thompson [43] established this theory to examine the link concerning IT plus individual performance. Goodhue and Thompson [43] wanted to confirm the idea that combining usage and task-technology fit can better clarify the performance of IT.

Sarker and Valacich [44] proclaim that the TTF theory argues that individuals form an opinion on the appropriateness of technology built on perceptions of how the technology supports their requirements. The TTF theory can be defined as the extent to which the capabilities of the technology counterpart the task's demand [43, 45]. Goodhue and Thompson [43] ascertain that a technology will be used when it conforms to, or fits the task of the user. According to Waite, et al. [46], the TTF is a theory that ascertains that a technology must be used to the best of its functionality and the technology must be a good fit with the task that it supports. According to Goodhue and Thompson [43], the TTF theory ascertains that for a technology to have an encouraging influence on performance, it is necessary for the technology to be used. It should be a 'good fit' with the tasks it supports. Figure 5 presents the TTF theory, where task characteristics and technology characteristics all combine to lead to the fit of a technology to a task. When this fit is achieved, it then leads to performance impact and utilisation.

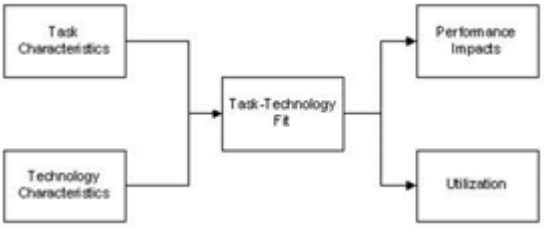

Figure 5: Task Technology Fit Model [43]

The TTF theory has been used in many studies of education [17, 44, 47, 48]. It was used in China where the basic characteristics and tasks of the 21st century education were evaluated. The researcher denoted that the 21st century is the age of knowledge-based and the central of task education in the age of knowledge-based economy is education for quality [48].

The TTF theory has been used in corporate companies [45, 49, 50]. It was used in a study that investigated the acceptance of Knowledge Management Systems (KMS). The aim of the study was to explore the effects of empowering leadership, task-technology fit and compatibility of the KMS. According to Kuo and Lee [45], empowering leadership, TTF are significant predictors of perceived ease of use.

The TTF has been used in the field of commerce [51, 52]. A study which combined the TTF and TAM to evaluate consumer e-commerce as a technology adoption process was conducted. According [52], TTF is a valuable addition to TAM.

The CUT provides free Wi-Fi. The TTF can be applied in evaluating the use of the free Wi-Fi by students. The TTF would evaluate the technology used for accessing the Wi-Fi. The results may indicate the link between the technology used for accessing the Wi-Fi and the performance of students.

VII. UNIFIED THEORY OF ACCEPTANCE AND USE OF TECHNOLOGY

The Unified Theory of Acceptance and Use of Technology (UTAUT) was developed by Venkatesh, Morris, Davis and David [53]. This theory is a more current model, which is a combination of eight present models of technology acceptance with the TAM [54]. Venkatesh, et al. [53] integrated these models to promote a unified view of user acceptance and to identify the most significant influences. Oshlyansky, et al. [54] proclaimed that the UTAUT model incorporates elements from the TRA, Motivational Model, the TPB, a combined TAM and TPB model, Model of PC Utilization, the DIO and Social Cognition Theory.

Each of these models covers a user's intention to use a technology or the actual use of a technology as the dependent variable. The variance in user intentions is explained between 17% and 53% [55]. By integrating the conceptual and empirical similarities of these eight models, the UTAUT model explains up to 70% of the variance in intention to use a technology [55]. According to Vanneste, et al. [55] the UTAUT model explains up to 50% of the variance in technology use. The UTAUT model constructs are performance expectancy, effort expectancy, social inference, facilitating conditions, use behaviour, gender, age, experience and voluntariness of use (see Figure 6).

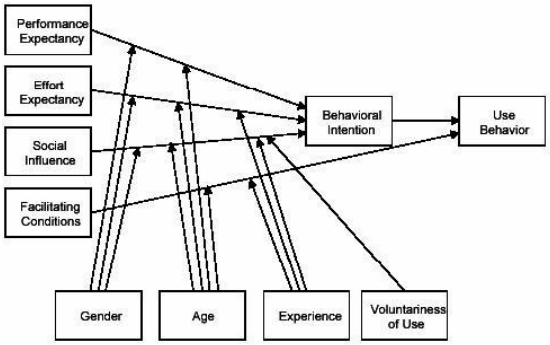

Figure 6: Unified Theory of Acceptance and Use of Technology [56]

In industrial Engineering, the UTAUT was applied in a study that evaluated the use of mobile 3G communication users. The study was useful in providing tactics and strategies for computer orientated 3G services to existing and potential customers [57].

The UTAUT was applied in E-Government systems. It was applied in a study to investigate the effects of web quality on adoption of E-Government services [58]. The UTAUT was also applied in Human Computer Behaviour. The study investigated the uptake of technology innovations in online family disputes resolution services [59].

At the CUT, the UTAUT can be used in evaluating the use of SAM from Cengage and Cisco Net Academy. These are both online learning systems used at the university and may well be under-used. The UTAUT can be applied to evaluate the acceptance of these online learning systems and to evaluate the student's behaviour towards them.

VIII. CONCLUSION

The aim of this paper was to review 6 unique Information Systems models of acceptance (Diffusion of Innovations, Theory of Reasoned Action, Theory of Planned Behaviour, Technology Acceptance Model, Task Technology fit and Unified Theory of Acceptance and use of Technology). These models can be applied in the in following ways:

- How technology can spread through culture.
- To measures one's relative intention to execute an action or specific behaviour.
- Studying the beliefs of individuals concerning the proprietorship of mandatory resources and prospects for execution of a given behaviour.
- How users come to adopt and use a technology.
- Examine the link concerning IT and individual performance.
- Evaluating a user's intention to use a technology or the actual use of a technology as the dependent variable.

The limitation of this paper is that the recommendations have only been made for the CUT. The CUT may apply these models in evaluating some of the technologies used. Indeed, technology acceptance is influenced by an individual's behaviour.

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Extending the Technology Acceptance Model for E-learning Discussion Forum Adoption

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Abstract **- The advancement on Information and Communication Technology and the Internet for educational purposes has been a staple discourse among researchers in recent years. However, preliminary investigations indicate that e-learning systems are underutilized due to the fact that some of their major features remaining inactive; features like electronic discussion forums. Despite several scholars reporting on high levels of e-learning systems implementation at Universities of Technology (UoT), it is disconcerting that discussion forums within these platforms remain poorly utilized. The purpose of this study is to establish constructs that may promote adoption and use of discussion forums. The Technology Acceptance Model forms the theoretical framework for this study and is extended by including digital inclusion, perceived attention and perceived enjoyment. Thirty participants were purposively selected from a third year Information Technology class and interviewed with regards to the different constructs which make up the Technology Acceptance Model. Findings of this case study suggest that, perceived usefulness and ease along with digital inclusion may positively influence adoption and use of discussion forums at UoT. The study contributes to the board of knowledge by providing useful insights into the application of the Technology Acceptance Model by establishing additional constructs that may promote discussion forum usage.**

Keywords **- e-learning, LMS, Blackboard, digital inclusion, perceived attention, perceived enjoyment**

1. INTRODUCTION

Africa's Internet usage is growing steadily. It was predicted that almost one out of ten households would be connected to the internet by the end of 2014 [1]. According to the International Telecommunication Union, household Internet access on the African continent is continually growing at double-digit rates (18% in 2014, more than twice the growth of the world average) [1]. This extraordinary growth of Information and Communication Technology (ICT) suggests that a remarkable digital inclusion exists among many Africans. Indeed, enhanced Internet access has the potential to improve many people's socio-economic development.

The effective utilization of ICTs in education may contribute to the socio-economic development of many communities in Africa. The possibilities of enhancing quality educational outcomes through ICT and Internet usage have been a staple discourse in recent years [2]. Previous studies have reported on the value of social presence in online engagement [3], the potential of collaborative learning to foster enhanced critical thinking [4], and the importance of interaction on any online teaching and learning system [5]. These studies have demonstrated the capacity of ICTs to unveil a world of potential within teaching and learning where lecturers and students can communicate on a level which will enhance the quality of the learning experience.

Internet usage are promising among Africans, as well as their potential to foster effective learning through online interactions. However, insufficient studies have explored the factors that influence students in adopting online discussion forums (DFs) at South African UoT. The purpose of this study is to establish constructs that influence adoption of e-learning DFs that may optimistically lead to effective learning. A case study is used where data collection is achieved through face-to-face interviews. Content analysis is used to establish themes that contribute to the establishment of factors that influence e-learning adoption among South African UoT students. The impact of e-learning and DFs will firstly be presented followed by the theoretical framework. Thirdly, the research methodology section outlines the research design and data collection instruments. Results and conclusions are finally highlighted.

2. LITERATURE REVIEW

A discourse on DFs is incomplete without an examination of the broader domain within which it exists. For this reason, this paper explores e-learning, the broader domain in which the adoption and use of DFs occur, as a precursor to examining DFs themselves.

2.1. E-Learning

E-learning can be defined as information delivered on a digital device, such as a computer or mobile device, for the purpose of supporting learning [6]. The following e-learning merits have been identified: better access control to learning material; students receive the exact same material; e-learning material is delivered in the exact same way which allows for consistency of content and quality of instruction [7].

In order for e-learning to be utilized in an efficient manner, ensuring its successful transition to more flexible modes of delivery, requires full, long-term commitment and support from senior management in advocating, fostering and monitoring this strategic change [8]. Academics and students need to attend more training sessions in using e-learning if it is to be widely adopted [9]. A study on the user acceptance of e-learning technologies further revealed that a lack of institutional strategy, lack of time, and lack of training support were three of the most critical barriers to the successful adoption of e-learning technologies [10]. Furthermore, academics need to put aside their traditional teaching styles, their reluctance to adopt change and their general perception of increased work load and be more open in accepting e-learning technologies as an alternative approach to the teaching and learning process [11].

2.2. Discussion Forums

Most institutionally supplied e-learning technologies, such as Blackboard, Moodle and Vula, include DFs as one of their affordances [12]. This provides a cyber space capable of providing increased engagements among academics and students [13]. DFs not only increase collaborative engagement between academics and students, but also provide for a flexible and anonymous learning environment outside the classroom [14]. Added to DFs are social networking platforms which have been cited as increasing student engagement with academics and their peers.

Some of these platforms include Facebook, twitter, Myspace, Mixit, and WhatsApp, which operate according to the fundamental principles of DFs. These platforms create opportunities for students to share knowledge with their peers and friends in a fun, informal environment [15]. Facebook should be used for academic purposes since many study groups have been created on Facebook that are being used by students to discuss homework assignments and share answers [16].

3. THEORETICAL FRAMEWORK

The Technology Acceptance Model (TAM) was originally developed by Davis [17] and is currently one of the most widely used theories in technological adoption. TAM is an adaptation of the Theory of Reasoned Action (TRA) within the field of information systems (IS). The TRA posits that individual behavior is driven by behavioral intention, where behavioral intention is a function of an individual's attitude toward the behavior and subjective norms surrounding the performance of that particular behavior. It suggests that perceived usefulness and perceived ease of use determine an individual's intention to accept and use a given technology [18]. Figure 1 presents the original version of TAM [17] which includes two major constructs addressing individual attitudes toward using new technology, namely perceived usefulness and perceived ease of use. Positive attitudes towards using an electronic based system positively affects behavioral intention to use such a system.

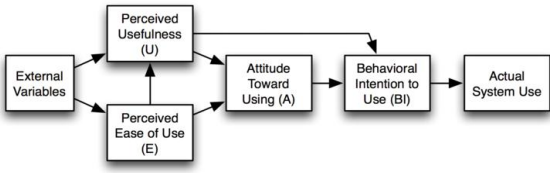

Figure 1: Original Technology Acceptance Model

Through the years, TAM has evolved and has been refined to include other variables and modified relationships. TAM has grown into a leading model in explaining and predicting technological system usage. It has become so popular that it is cited by many researches who consider user acceptance of technology [19] .

The TAM was selected for this study due to its predictive ability in studies involving students in technology adoption [20]. It was used to investigate factors that influence adoption of Blackboard e-learning DFs [21] at a UoT in South Africa. Davis [17] posits that practitioners should evaluate technology for two purposes: 1) to predict acceptability; and 2) to diagnose the reasons resulting in a lack of acceptance and to take proper measures to improve user acceptance. In this study, TAM was extended with digital inclusion, perceived attention, and perceived enjoyment.

4. RESEARCH METHODOLOGY

A qualitative case study is used where data is collected using semi-structured interview. Senior Information Technology (IT) students registered for the Information Systems III module at the Central University of Technology (CUT) constituted the target population. These students (147 in number) made use of DFs within the Blackboard learning management system (LMS called eThuto) during 2013 in order to improve their engagement with their course content, peers and academics. Since the exploration of student motivation to use discussions forums formed the basis of this study, purposive sampling was ideal for the selection of research participants. Qualitative case studies often require a number of interviews to be conducted until data saturation occurs. In this study, data saturation was established after 30 participants were interviewed, thereby establishing the sample size for this study.

Face-to-face semi-structured interviews were used to where the constructs of the TAM formed the focal areas of discussion. Content analysis was then applied to analyze the responses which were recorded during the 35 minute interview.

5. DATA ANALYSIS AND DISCUSSION OF FINDINGS

Considering that the main focus of this study is to gather students' perceptions and experiences of using and accepting DFs, it was therefore decided to use content analysis to analyze the qualitative data. The TAM constructs provided guiding themes for content analysis.

Each subsection starts with a definition of the construct and then presents the specific question asked to the participants in this study with their responses following suit. The number in brackets after the responses represents the number of students who indicated similar answers.

The sample consisted of Africans from different racial backgrounds, 18 being males and 12 females. Although gender representation was skewed in favour of males, this anomaly is simply indicative of the higher enrolment and participation rates of males in Science, Technology, Engineering and Mathematics (STEM) at universities. Participant ages ranged from 22 to 30 years of age. Nineteen participants had never used DFs before, while six had never heard about them.

5.1. Digital Inclusion

According to Washington State University [22], digital inclusion refers to individuals and disadvantaged groups having access, and the necessary skills required to use ICTs, thereby enabling them to take part in and benefit from an institution's growing cognition and information society. Selwyn & Facer [23] posits that digital inclusion occurs when all members of society are able to access the affordances offered by technology.

What challenges do you experience in your use of DFs?

Participants noted the following:

> Access to computer facilities have improved drastically over the past few years as it was a challenge to only make use of the computers in the library building. (1)
>
> Access to electronic devices such as laptops, tablets and smartphones has been promoted by the institution, which has helped to minimize a previous challenge of affordability. (1)
>
> I experience challenges in using DFs, but it would be a good idea for the university to appoint someone who would be responsible for providing additional help to students who struggle with the system. (9)

Are you aware of E-Thuto DFs?

> I am aware of DFs but have never received any sort of training. (28)

How can the University improve E-Thuto DF awareness among students?

> The university should make more students aware of DFs whether it is through a short course, a workshop or just a quick introduction in class. (12)
>
> It all comes down to the lecturer. They should introduce DFs to students and keep on reminding us to use it. (10)
>
> The use of smartphones for learning are so widespread that students can use them to go onto the university's LMS and access DF from anywhere and at any time. This fact will make competitions on DF a really good idea. Within no time, students will know about the competition and what they could win and thus many will know about and use the DF. (1)

The combination of readily available facilities and proper training could motivate students more to use DFs for educational purposes. Studies on the topic of ICT usage in the digital divide context have focused on examining demographic characteristics of users, such as gender, income, and level of education [24]; analyzing patterns of use [25]; and identifying benefits of use [26]. This study, however, adds to existing research by identifying the construct of digital inclusion that influences student usage of DFs within the Blackboard e-learning system.

5.2. Perceived attention

According to John Keller's ARCS (Attention, Relevance, Confidence, and Satisfaction) model, attention can be gained in two ways - perceptual arousal and inquiry arousal [27]. Perceptual arousal comes from using surprise or uncertainty to gain interest. Inquiry arousal stimulates curiosity by posing challenging questions or problems that need to be solved. During this study, the aim was to gain insight into which instructional approaches capture student's attention within the DF, if any.

What learning modes (e.g. text, video, graphics etc.) within E-Thuto DFs do you know?

> Students are not aware of the different learning modes within blackboard e-learning DFs and they use them mostly to text their peers. (28)

Are you motivated to learn by using various learning modes?

> Students would be more motivated to learn if they had been made aware of these different learning modes. (19)
>
> At times, students only go onto DFs when they are desperate for more information, for example just before a test; and different learning modes would definitely motivate them to go back more often. Even if discussions are not of an educational nature and they get an opportunity to get to know their peers, this would be great because in a class of 200 students, it is difficult to get to know each other. (1)
>
> Different learning modes, like pictures, audio and videos would make it easier and capture one's attention. Students would also not be limited to using only text. (1)

The researchers infer that the visual appeal and auditory affordances of online DFs may draw the attention of learners and motivate them to use them for educational purposes. In support of this statement, Felder & Siverman [28] posits that although there are numerous styles with which students learn, it would be sufficient for an instructor to include a relatively small number of techniques to meet the needs of many students in any class. The participants'

claims about perceived attention are consistent with Keller's [27] findings that the use of various instructional approaches motivate student attention to engage in academically productive activities. Keller [27] elaborates that students who perform well through the use of the same tried and true method of instructional approach will benefit from variation. As such, the variations of modes of information have the potential to capture and retain the attention of students with diverse learning styles.

5.3. Perceived enjoyment

Perceived enjoyment (PE) refers to the extent to which the activity of using computers is perceived to be enjoyable in its own right, aside from any academic consequences that may be expected [29]. Sun & Zhang [30] claims that perceived enjoyment plays a vital part in user technology acceptance and has great significance, especially for hedonic systems.

Do you find E-Thuto DFs pleasant?

> I perceive DFs to be pleasant. (26)
>
> It is enjoyable using DFs, but then threads should not go too long unanswered. (2)
>
> It is nice when everyone comes up with their own ideas and opinions about something. It is very interesting to see what others think and how their thoughts differ from your own. (1)
>
> DFs create that 'extra class feel', but in a fun way. It is enjoyable to learn so much from your peers and in turn contribute by sharing your knowledge with others. It is not fun studying alone, but knowing that there are others whom you can ask for help should you struggle. (1)

Do E-Thuto DFs offer you playful learning?

> I enjoy receiving replies on my posts and, with the help of my peers, getting to the correct answer. Through this exercise we realize mistakes and also learn from our peers (18).
>
> I see DFs more as a learning experience whereas sites like Facebook or Whatsapp offer me a more playful environment. (8)

How can E-Thuto DFs be more pleasant to students?

> Competitions or promotions would be effective in motivating students to use DFs. (4)
>
> Using different learning modes, such as uploading videos, pictures, or recordings of classes, would make the DF more pleasant. (10)

Van der Heijden [31] extended the TAM with perceived enjoyment and perceived attractiveness in order to address users' motivation toward the acceptance of websites. In van der Heijden's study, perceived enjoyment refers to "the extent to which the activity of using the computer is perceived to be enjoyable in its own right, apart from any performance consequences that may be anticipated". These findings suggest that the inclusion of perceived enjoyment and attractiveness with the original TAM constructs provided the right combination of measurements to accurately test user adoption of a web-based system. The incorporation of short threads, different learning modes and promotions within the DFs may lead to an improved adoption of this e-learning system.

5.4. Perceived ease of use

Drawing on the TAM [17], perceived ease of use refers to "the degree to which a person believes that using a particular system would be free from effort".

Did you find it easy to become proficient in using DFs?

> I feel that the system was user-friendly. My prior DF knowledge and operational instructions given by the tutors helped me to become proficient in using the DF. (30)

Participants' experiences with the ease of use of DFs indicate that this construct influenced their willingness to adopt DFs for learning. These findings are in line with previous findings from technology adoption studies that perceived ease of use influences technology adoption [21]. However, findings of this study regarding the ease of use are contradictory to Danner & Pessu [9] and Nanayakkara & Whiddett [10] who state that user training, which improves ease of use, causes underutilization of educational systems. Possible reasons for this contradiction can be that the technology considered in this study (which is a DF) is a component of the entire LMS which participants are proficient at.

5.5. Perceived usefulness

Perceived usefulness is defined by Davis as "the degree to which a person believes that using a particular system would enhance his or her job performance" [17].

Do you find E-Thuto DFs relevant/useful to your learning?

> Blackboard e-learning DFs were useful to my learning and definitely enhanced my performance. (30)

Have your grades improved by using E-Thuto DFs?

> I believe that Blackboard e-learning DFs contributed to my improved grades. (30)

Previous studies reported that perceived usefulness positively influences technology adoption [21]. These authors' findings have been corroborated with the participants' perspectives in this study. This further affirms the findings from [32] on the significant impact of perceived usefulness on attitudes toward using mobile banking.

5.6. Attitude towards using DFs

Attitude refers to an individual's positive or negative feelings about performing a targeted behavior, for example, behavior to the use a specific system. It involves an individual's judgment that performing a behavior is either good or bad and also a general evaluation that an individual is inclined or disinclined to perform the behavior [33].

What is your general attitude towards using E-Thuto DFs?

> I have a very positive attitude towards using DFs and feel that it is very helpful in my learning. (28)
>
> I have a complaint about posted questions that are left unanswered or about the types of discussions that have been initiated by my lecturers. (2)

Therefore, unlike the uptake of emerging technologies (mobile phones) by the elderly, where the intention to use the technology is influenced primarily by external factors (such as objectification which includes filial affection, safety and security [34]), student's attitude towards the use of DFs were generally positive. The relevance of DFs to student learning is expressed in their belief that DFs helped to improve their academic performance. This runs parallel to findings that ease of use has little influence on elderly users accepting and using available functionality of emerging technologies (e.g. mobile devices), leading to them deriving sub-optimal value from their usage [34]. Furthermore, wholehearted adoption can only occur if the adopter fully accepts the technology. If not, he or she is unlikely to progress fully and therefore remains a reluctant user of the technology. Perhaps a reason for this contradiction is that while the research participants for this study were trained on the use of DFs, thus contributing to their improved ease of use, the elderly usually lack sufficient training on the use of mobile phones often handed down to them by relatives or friends.

5.7. Behavioral intention to use DFs

Behavioral intention is defined as "the degree to which a person has formulated conscious plans to perform or not perform some specified future behavior" [35]. A high majority of participants demonstrated a positive behavioral intention towards the usage of Blackboard e-learning DFs.

In which other courses would you like E-Thuto DFs to be utilized?

> DFs should be introduced into all our subjects as it would increase student performance. (29)
>
> I am concerned about introducing Blackboard e-leaning DFs in all my subjects as it might be too overwhelming. (1)

Will you reuse DFs in the future?

> I will definitely reuse DFs in the future, especially if other students and educators are active on them, or if I come across a question I wanted the answer to and could not answer myself. (30)

Will you continue using DFs even if new threads are not created by the lecturer or other students?

> I will continue using Backboard DFs in order to help others by sharing my knowledge; or I will ask questions should I need assistance. (28)

Park [36] measured university students' behavioral intention to use e-learning. Results from Park's study indicated that the majority of participants intend to become heavy users of e-learning systems and that they intend on checking announcements from e-learning systems frequently. The validated TAM provides a useful framework for technology implementers who needed to assess the possibility of success for technology innovations and to pro-actively design technology based campaigns [37]. That said, some caveats should be provided as a minority of participants were skeptical about whether they would use DFs persistently, especially in responding to new threads posted by amateurish or inexperienced peers, whose credibility could not be confirmed. Most participants believed that they would continue to use the Backboard DFs in order to help others by sharing their knowledge; or to ask questions should they need assistance.

6. CONCLUSION

The study provided some insights on blackboard e-learning discussion forum usage. The original TAM constructs namely, perceived ease of use, perceived usefulness, attitude towards use and behavioral intention to use Blackboard e-learning DFs, were found to be the drivers for technology adoption. These findings are consistent with TAM related findings by previous studies [17].

This study's findings indicated that the additional constructs that were incorporated into the original TAM had a positive influence on 1) motivating students to adopt DF for learning purposes (digital inclusion); 2) capturing students attention of using DFs for learning purposes due to their visual appeal and auditory affordances (perceived attention); and 3) in motivating students to participate in DFs due to the different learning modes which exist (perceived enjoyment). The researchers concludes that underutilization of electronic DFs is associated with a lack of awareness of such e-learning affordances.

This study confirms that TAM is a valid model for assessing backboard discussion forum utilization within UoT in South Africa. The study extended the TAM with digital inclusion, perceived attention, and perceived enjoyment, thus contributing to the board of knowledge by providing useful insights into the application of the Technology Acceptance Model by establishing these additional constructs that may promote discussion forum usage.

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Investigating the Low Pass-Rate of CCNA1 Students at the Central University of Technology

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***Abstract* - The field of Information Technology (IT) has experienced rapid change over the past few decades. Since the late 90's, many businesses in the IT industry begun to require certifications for specific technologies. Corporations begun to collaborate with traditional educational institutions so that they can control the quality and content of students that have the desire to learn their networking concepts. The Department of Information Technology (DIT) at Central University of Technology (CUT) adopted the Cisco program and teach students the Cisco curriculum. Cisco curriculum is the most widely used computer networking curriculum and the international standard by which professional competency in this field can be measured. The DIT has been experiencing a decline in student pass-rate and this has raised a lot of concern. Hence, the main aim of this research project was to investigate the low pass-rate of CCNA-1 students at CUT. Due to time constraints, this research examined the delivery method and the assessment method as they might influence student success. The quantitative research design allowed the researcher to collect both qualitative and quantitative data using an online questionnaire from 2015 and 2016 CCNA-1 students from the DIT at CUT, Bloemfontein campus. The questionnaire was administered to 188 students at the end of the second semester. The data was coded and analysed manually using Microsoft Excel. From the results it is very clear that students do not make time to study and they do not visit the library to expand on their knowledge. Some of the students indicated that the content they received was too much and coupled with little contact time they have with the lecturer, exacerbated the situation. 53% of the participants suggested that the delivery method must be improved.**

***Keywords* - CCNA-1, student pass rate, CISCO, student success, delivery methods and assessment method.**

1. Introduction

The field of Information Technology (IT) has experienced rapid change over the past few decades. Since the late 90's, many businesses in the IT industry begun to require certifications for specific technologies [1], [2]. Prospective employers frequently stated that they are paying less attention to the results or progress reports of the graduates when hiring new employees but rather concentrate on whether the candidate has the relevant certification or not [11]. IT professional certifications are being increasingly used as indicators of professional skill. The certificate programs have high international standards approved by international institutions for example CISCO Corporation and Microsoft Corporation [18]. As a result, some of these Corporations begun to collaborate with traditional educational institutions so that they can control the quality and content of students that have the desire to learn their networking concepts. The Department of Information Technology (DIT) at Central University of Technology (CUT) also adopted this program and teach students from first, second, third to fourth year the Cisco curriculum.

Cisco Systems designed and developed a global education initiative called Cisco Networking Academy, which offers networking programs like the Cisco Certified Network Associate (CCNA), CCNA Security and Cisco Certified Network Professional (CCNP) courses. Since 2007, these programs prepare students for the certification exams of the same name, and other computer-related courses. In 2010, the programs were available in roughly 9,000 local academies, in over 165 different countries and there were over 900,000 active students. Cisco curriculum is the most widely used computer networking curriculum and the international standard by which professional competency in this field can be measured.

South Africa (SA) suffers from one of the most enduring high rates of unemployment [12]. There are a number of notions to explain this persistent high rate of unemployment. Some researchers argue that this is due to the high number of school leavers who either failed the grade or dropped out of the education system [12]. These school leavers are the exact generation we are looking for who have the potential to turn the economy around. This is exactly what the DIT has been experiencing, a decline in student pass-rate and this has raised a lot of concern. The DIT at CUT has adopted the Cisco program for a while now and teach students from first, second, third and fourth year Cisco curriculum, which is

CCNA 1-4 and CCNA Security. The student pass rate for the first semester of 2015 was 58%, meaning 42% of the students failed the CCNA-1 course and in 2014 only 63% of students passed.

Hence, the main aim of this research project was to investigate the low pass-rate of CCNA-1 students at CUT. Due to time constraints, this research examined the delivery method and the assessment method as they might influence student success. This paper is structure as follows: Section 2 discusses CCNA-1 course background, Section 3 give a detailed research methodology for the project, the findings are presented in Section 4 and Section 5 presents the discussion based of the findings. Sections 6 presents the limitations of the project and Section 7 concludes the project.

2. CCNA-1 Course Background

The Cisco CCNA curriculum consists of four components covered in four semesters each of which covers between seven and eleven topics. Each component/semester builds on the previous one and each topic progresses from simple concepts to the more complex. The four components are listed below:

1. Networking Basics (CCNA-1)
2. Routers and Routing Basics (CCNA-2)
3. Switching Basics and Intermediate Routing (CCNA-3)
4. WAN Technologies (CCNA-4)

Currently at CUT, each component is covered in two school semesters (6 months), meaning the students and the lecturer must have covered about 11 Chapters in less than 5 months, each chapter covering approximately about 30-50 slides (normally prepared by CISCO). Compared with the other three CCNA components, CCNA-1 has enormous amount of theory to be covered, with diminutive practical component.

The practical work involved in the course is designed to support the theory and vice versa. There are four key components to the Cisco Networking Academy environment: 1) a centralized curriculum distributed over the Internet; 2) standards-based testing distributed over the Internet; 3) locally customized instruction; 4) practical component, either on real equipment or on simulation and 5) an instructor support system for training, support, and certification.

2.1 Current delivery method

Porto & Aje [16] and Owen *et al.* [15] concur on what a course delivery method is. They define it as decisions about how to present the content, activities, and assessments that are designed into the course. The literature review we conducted looked at different delivery methods and currently there are mainly seven (7) delivery methods implemented and are as follows:

Table 1: Delivery methods and their definitions

Delivery method	Definition
Lecture/Demonstration	In-person lecture/demonstration on a particular topic with limited interaction and practice
Classroom Training with Instructor	Participants attend training where an instructor presents material and there is an opportunity for interaction and hands- on learning or practice.
One-on-One Tutorial	Instructor provides individual instruction to one learner.
Self-paced Learning, Non-electronic	Learner follows a course of study, setting own learning pace (e.g., with printed materials such as books or manuals, not via the Internet).
E-learning, Self-paced	Training delivered electronically (e.g., computer-based via the Internet or with CD-ROMs) in which learner sets own learning pace.
E-learning, Facilitated	Instruction delivered electronically with an instructor or facilitator who sets the pace and/or offers interaction (e.g., webcasts or scheduled Internet instruction).
Blended Learning	Combines e-learning with instructor-led classroom training or one-on-one instruction.

The current delivery method used at CUT is the typical face-to-face traditional approach, where most of the learning occurs in the physical classroom. The students attend one theory class for an hour and a half and two practical classes (for an hour and a half each) per week. Due to the sheer volume of theoretical concepts which need to be imparted to the students, there is no significant interactivity in the class between the peers and also with the lecturer. This instructive, one-way communication medium, involves the lecturer 'pushing' the information to the students and the students tend to be in a passive role and are expected to progress in a linear sequenced fashion through a pre-planned curriculum which when completed should signify that learning has occurred [4] Dyke. The students can also attend an optional SI class conducted by a senior student to reinforce some of the concepts covered in theory class. Web-based storage of course materials is utilised but no web-based learning is integrated. Unfortunately, this requires students to have internet connection to be able access the material when outside the campus. It is the same with the recommended textbooks, these books change every time the curriculum is

updated which is mostly every 2-3 years and they are relatively expensive to own.

For the practical component, the students can access the labs to complete their practical work at any time. The hands-on labs, which are provided as part of the CCNA curriculum, follow an example-based learning approach which gives the student an expert's method of how to complete the lab exercise. These labs provide opportunities for students to be actively engaged and also allow students to socially collaborate with their peers and receive guidance from the instructor when necessary.

If no lab is available, the students can also make use of simulator (Packet Tracer) activities that are available to help the students to practice and assess their practical skills. The Packet Tracer (PT) simulator is a cross-platform visual simulation program designed by Cisco Systems, it allows students to create network topologies and imitate modern computer networks. PT allows students to simulate the configuration of Cisco routers and switches using a simulated command line interface. The simulator makes use of a drag and drop user interface, allowing students to add and remove simulated network devices as needed. The software is for free, students can download it and install it on their laptops or computers at home.

2.2 Current assessment method

Assessment has a long history in education [10]. Tests have been employed in schools for a very long time and their use has amplified immensely since the turn of the last century [17]. The development and propagation of ability and intelligence testing stimulated the dramatic growth in school testing [8]. Such that, the use of tests in schools became very common in many countries throughout the years and these tests have improved over time. The literature the researcher reviewed indicated that there are three (3) types of assessments currently used. Table 2 lists these types of assessments.

Table 2: Types of Assessments

Assessment type	Description
Diagnostic	Before instruction begins, used to determine mastery of prerequisite knowledge and skills and prior knowledge of future content (e.g. reading readiness test).
Formative	Throughout a unit and lesson cycle, used to gauge progress (e.g. weekly quizzes).
Summative	At the end of a unit or end of the year, used to measure growth and achievement formally (e.g. end-of-unit test).

The assessment methods currently used include formative and summative assessments, no diagnostic assessment method is used. The assessment structure includes:

- chapter on-line tests
- assignments
- class tests
- final online test
- quizzes
- practical tests
- written exam

The students write their chapter online tests immediately after the chapter is completed in class. The Cisco online test system allows the students to get immediate feedback on their mistakes. Students are encouraged to complete these tests as they form part of their final mark for the subject, although these chapter tests count only 1% each. All the online tests are multiple choice questions which assess various levels of learning outcomes, from basic recall to application, analysis, and evaluation. The written tests and examinations make use of a combination of questions including multiple choice, fill-in the missing word, case study, true/false, sometimes computational and short answer questions. The literature argues that the ability to recall information does not constitute learning, but the ability to apply it to unforeseen problem-solving situations does and case studies assist in this area. The assignments come in different forms, it can be a case study or research. This allows students to start considering research, what research is and how to conduct research. Because of the number of students we enroll in this course, it is not possible to conduct practical tests on real equipment and hence PT tests are the most preferred tests.

Irrespective of all these delivery and assessment methods put in place, the DIT at CUT has experienced a decline in CCNA-1 student pass-rate and it has raised a lot of concern. The student pass rate for the first semester of 2015 was 58%, meaning 42% of the students failed and in 2014 63% of students passed.

3. METHODOLOGY

It was adamant that a comprehensive enquiry was needed to investigate and analyse the underlying issues/problems that caused this humongous failure rate. The research methodology used for this study was a quantitative research design, though the data was analysed both qualitatively and quantitatively. The collection of both quantitative and qualitative data allowed triangulation to be applied between the various datasets adding validity and credibility to the study.

3.1 Participants

The participants were 2015 and 2016 CCNA-1 students studying at the CUT, Bloemfontein campus. CCNA lecturers at CUT were also consulted for their views on the questionnaire and to also get some of their opinions on this issue. Approval to conduct the study was obtained from CUT and all participants that were selected gave informed consent subject to confidentiality and anonymity.

3.2 Data collection method

In order to examine student perceptions, an online survey was developed and delivered using Google forms. The questionnaire comprised of a combination of dichotomous, nominal, rating scale, bipolar, open-ended and contingency questions that gathered straightforward information relating to the participant's study behaviour and basic opinions on the delivery and assessment methods used in CCNA 1 course. The questionnaire consisted of five Sections made up of 66 items that covered such areas as Student background information, Student study behaviour, Opinions on delivery method, Opinions on assessment method and Opinions on general issues.

A pilot test was done in order to inform the survey design process. The questionnaire was evaluated by several content and methodological professionals in order to assess bias, ambiguity, or potential semantic problems. Firstly, the questionnaire was circulated to other CCNA instructors in an attempt to attain their views on their students learning experiences while studying CCNA and to reveal different approaches taken to teach this subject. Secondly, the questionnaire was given to an expert in the Education Department so to get views on the structure and appropriateness of the questionnaire. Finally, the questionnaire was pilot tested prior to implementation in order to test the efficacy of the research methodology and was modified accordingly. The questionnaire was administered at the end of the semester, just before the exams. From 248 students who were registered for the course, 188 completed the questionnaire.

3.3 Analysis

During the data analysis process descriptive statistics such as the average or median were generated to help understand the data. Frequency distribution were also generated and examined. The data was coded and analysed manually using Microsoft Excel.

4. Findings

The There were 188 participants, 67% percent were males and 33% were females. In terms of age, 46.3% of respondents reported being between 22 and 24, 45.7% said that they were between 19-21. The participants were 2015 and 2016 CCNA-1 students, the 2015 cohort have passed CCNA-1 class and now doing CCNA-3. The 2016 cohort is a mix of new students from first year and student who have failed the CCNA-1 in 2015 and now repeating the course. This allowed the researcher to collect data from all three groups of students (new, passed and failed). From the 185 responses, 61.6% of the participants were in the 2016 group and 38.4% were in the 2015 group. The participants were asked for their student numbers for the follow-up focus groups, 80% of the respondents voluntary provided their student numbers. Only 51% of the respondents prepare before class and 50% study after class. Fifty-three percent of the respondents participate in class discussions or activities and 56% never visit the library for referencing purpose.

Sixty-four percent of the respondents think that the delivery method supports effective learning and 61% think that it helped them understand the content very well. 59% of the respondents think that the delivery method supported their learning style and 63 % think that the delivery method fostered a transfer of knowledge and skills to students. While 62% of the respondents think that the delivery method fosters creative thinking. The results indicate that the delivery method allowed collaboration, group discussion and peer learning with participants rating them as 61%, 68% and 69% respectively. Strangely, 53% of the respondents feel that the delivery method needs improvement. It was important to investigate and measure the delivery method, such that improvements can be made if necessary. The participants who strongly agreed to the statements relating to the delivery method yielded a mean score of 39.64 with 8.33 standard deviation. Whereas, the participants who strongly disagreed to the statements relating to the delivery method yielded a mean score of 14.64 and 3.56 for standard deviation. This means that if improvements are necessary to the delivery method, they will be minor. The participants were asked what improvements would they like to see with regards to the delivery method. Following are some of the responses:

Table 3: Improvements to the delivery method

Resp-1	Lecturer should spend more time on things we battle with
Resp-2	Lecturers that just don't read the slides, but that interact with the students during class
Resp-3	More questions to the students during theory class
Resp-4	More classes per week
Resp-5	The theory is too much

The participants both agreed (36%) and strongly agreed (33.5%) that the online questions were relevant and aligned to the delivery method, whereas few of the participants disagreed (19%) and strongly disagreed (11.5%) with that. Also, sixty-eight percent of the participants agreed that the written questions were relevant and aligned to the delivery method, while 32% disagreed. 65% of the participants also concurred that the practical questions were relevant and aligned to the delivery method. These results indicate that the delivery method is proper and has been accepted, probably improvements to the delivery method would be minor. Ninety-seven (52%) participants agreed that the course was difficult. When the participants were asked to rate the difficulty/easiness of the course, 2% of the participants said the course was very easy and 10% said it was very difficult. 54% of the participants think that the course should run over a year, while 39.7% think that the current six months is just fine. Some (52.5 %) of the

participants prefer to work alone, while 47.5% of the participants prefer to work in a group. 10% of the participants said they would not recommend the course because "the course is too difficult", "more access to content is needed", "I just don't like networking", "Its too basic and not that realistic", "not enough time is given for both theory and practical".

5. Discussions

It is quite clear as indicated by the results that students do not make time to study, whether before class (preparation) or after class (emphasis). The students also indicated that they do not visit the library to expand on their knowledge and what they have learnt in class. Unfortunately, it is the responsibility of the student to take his/her studies seriously and make efforts to study beyond what is taught in class in order to develop themselves. Lecturers can give as many exercises and assignments as they want but if the students are not ready to take their own studies seriously, then no one will. But, some of the students indicated that the content they received was too much and this coupled with little contact time they have with the lecturer, exacerbated the situation. The CCNA-1 curriculum is a rich thick content which comprises of online course material, books, animations, hands-on laboratory and Packet tracer exercises. Moreno [14], Handelsman [7] and Mayer [13] say that there it is a well-accepted axiom in education that the more information a student has, the better his learning experience will be and the more information he will retain for future recall and reuse. The students are presented with large amounts of rich thick content and the over-abundance of information can have so much negative impact such as cognitive overload, surface learning (students put minimal effort in to order complete the task) and students become reluctant to invest time in areas which are not directly assessed.

Based on the findings, 53% of the participants suggested that the delivery method must be improved. Amongst the comments the students made, two themes emerged: "lecturers should spend more time on things the student battle with" and "lecturers are currently not interacting with students during theory class, they just read the slides". This will require that lecturers constantly adapt to meet students' changing needs and strengths on a particular task, as suggested by [19], [20]. Also, the instruction should consist of experiences that facilitate knowledge construction, instead of simply transmitting knowledge from lecturer to students [6], [13], [21].

The second issue the students mentioned is that the lecturers are currently not interacting with them during theory class. Wessels *et al.* [20] submit that the main difficulty with the lecture mode of teaching is the lack of interactivity with the students. Kafai & Resnick [9] and Felder [5] suggests that learners are more likely to create new knowledge when they are actively engaged in making some external artefact which can be reflected upon. Cameron [22] concur with Wessels et al. [20] that increasing the students' level of interactivity in class enables deep learning and have a positive effect on their motivation, attention span and the development of cognitive structures.

The findings also indicated that students do not understand most of the work but they memorise the content in order to pass the tests. This means that students are engaging in surface learning. It quite evident that the problem is the students' learning styles that needs interrogation and not the current assessment method as we predicted. Probably it is essential that we revisit what learning is and how students learn. Then the assessment methods can be evaluated based on that. It is indispensable that the delivery and assessment methods must be improvement, accompanied by a thorough assessment of the content itself and the relationship it has with the timeframe. This should be purely for our context and not in comparison with other universities more especially universities from abroad.

6. Future Research

This study proposed areas of improvement in CCNA-1 course and the proposed solution may be used as means of enhancing development of meaning for the students, in an effort to ameliorate their success in the course. Due to time this research project only focused on two key issues but following is a list of all or some of the issues/problems that require comprehensive investigation, review and critical analysis:

- the four components of the CISCO program mentioned in Section 2
- delivery method,
- learning materials (e.g. books, online material, practice tests, slides, etc),
- assessment methods/strategies,
- curriculum (course content),
- study period and
- the students.

7. Conclusion

Higher education is evolving and the teaching and learning methods and strategies should also evolve. For this reason and together with the low pass rate at CUT, has provided the impetus for the researcher to explore the current delivery and assessment methods used in CCNA-1 course. Improving student achievement cannot be done without understanding the critical classroom processes of Curriculum, Instruction and Assessment. This study evaluated the current delivery and assessment methods and discovered that compared to what we predicted, students engage in surface learning and also some of the students do not take their studies seriously. There is no doubt that the delivery method requires improvement and this research project proposed a multidimensional approach that has the potential to provide personalised student-centered teaching and learning. But the

proposed approach is restricted by the current environment (rich content and number of students) as well as the timeframe. A thorough research is required that will look at student learning and student learning styles, which will eventually influence the delivery method.

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Student Voices regarding Practical Work done in a Mechanical Engineering Laboratory reveals Satisfaction!

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***Abstract*- Students can validly comment on the quality of teaching as they directly experience it and their comments are important to evaluate the nature and quality of educational interventions. The purpose of this paper is to consider student voices regarding practical instruction offered in a Mechanical Engineering laboratory, as this may indicate student satisfaction with the course material. An exploratory study is employed along with descriptive statistics involving quantitative analysis of the collected data. The target population is restricted to undergraduate engineering students enrolled during 2014, who completed a questionnaire survey using an electronic response system. Results indicate that the students perceived the practical experiments conducted in a laboratory to be enjoyable, beneficial, challenging and relevant to the theory covered in a classroom. These results further suggest that students are being exposed to practical work that may contribute to the development of practical skills and graduate attributes required of students to add value to the socio-economic development of South Africa.**

***Keywords*- Perceptions, perspectives; student satisfaction, graduate attributes**

I. INTRODUCTION

"He who loves practice without theory is like the sailor who boards ship without a rudder and compass and never knows where he may cast". These words, by Leonardo da Vinci, clearly demonstrate that theory and practice must be integrated in order for any student to reach the final destination of demonstrating the achievement of important graduate attributes required by industry today. Although practical skills make up a significant part of an engineering curriculum at a university of technology (UoT), the current emphasis of *engineering education* in South Africa (SA) is to build attributes that will enable graduates to engage in life-long learning. The Central University of Technology (CUT) has prescribed ten student graduate attributes which students must demonstrate through their entire diploma or degree. These include sustainable development, problem solving, entrepreneurship, community engagement, technological literacy, numeracy, teamwork, communication, leadership and technical competence. Many of these attributes may be assessed within a laboratory environment, where engineering students are required to integrate their theoretical knowledge with their practical work [3]. Furthermore, a drive should exist to enable students to apply their theoretical knowledge in practice in order to add direct value to the socio-economic development of their communities, a drive which has been encouraged for many years [1, 2].

CUT offers a National Diploma in a number of engineering disciplines and is therefore mandated by the Engineering Council of South Africa (ECSA) to provide quality *engineering education* programs that will ensure that SA has an appropriate supply of competent engineering personnel with the appropriate graduate attributes [3]. Several of these attributes are assessed within laboratories at CUT, where engineering students are required to integrate their theoretical knowledge with their practical work. Previous research has shown that undergraduate students in an electrical engineering curriculum really enjoyed their practical work scheduled in a laboratory, feeling that the practical work was relevant, challenging and beneficial [2, 4, 5]. Laboratory work, or hands-on activities, can improve student understanding and lead to high student satisfaction with the learning experience [6, 7]. However, this was reported on only for students in an electronic communications course, with fewer results published for undergraduate engineering students in other disciplines at a university of technology. The following research questions therefore arise: What are the perceptions of undergraduate students with regard to practical work done in a Mechanical Engineering laboratory? Do they find the practical work to be enjoyable, relevant, challenging and beneficial?

Student voices are often associated with student feedback or perceptions. Listening to student voices on aspects relating to their educational experiences is an inexpensive, simple and efficient research method to gather information [8] that allows different aspects of the learning environment to be assessed on the basis of the individual student [9]. It must though be noted that student voices are really only personal assessments and views of practices [8]. However, these voices constitute a mental representation of learning activities that affect student's conscious and unconscious choices in the learning environment [10]. Students can validly comment on the quality of teaching as they directly experience it [11] and are important to evaluate the nature and quality of educational interventions [12]. In fact, a key dispositional factor, emerging from the literature that serves to enhance or inhibit student retention is their satisfaction with their course experience [13, 14]. This process of listening to student voices is also a key way to carry out teacher action research [15] which is a very important kind of education research that is especially valuable for demonstrating and evaluating classroom practices and linking theory and research to practice [16].

The purpose of this paper is to consider student voices regarding practical instruction offered in an Applied Strength of Materials laboratory within the Department of Mechanical and Mechatronics Engineering at CUT. Reasons for listening to student voices are first discussed, along with specific practical experiments that have been linked to the theoretical sections within the context of the case study used in this research. The voices of undergraduate engineering students, enrolled for a module in the National Diploma: Mechanical Engineering qualification at CUT were obtained using a questionnaire administered by means of an electronic response system, which forms part of the research methodology. Descriptive results are provided in a series of graphs with succinct conclusions at the end. It is important to note that the author was not involved with the practical work or course material, but simply reports on the voices of students regarding practical work to highlight that it is beneficial in promoting student satisfaction and engagement.

II. BENEFITS OF STUDENT VOICES

Student voices are part of all conversations about teaching, learning, and reform, as educators and policymakers have recognized that not only do students have a right to be heard but they also take the responsibility for education seriously [17]. Student voices or feedback is often obtained in order to determine the students' satisfaction regarding the quality of the education which they have received [13, 14], and has been used to improve the quality of engineering education study programs [18]. Student satisfaction within a specific course or module is an important variable influencing student retention [13, 14], and may lead to students recommending the course or module to fellow students in subsequent academic years. Furthermore, effective feedback is aimed at enhancing learning and teaching by allowing one to compare the actual outcome with the desired outcome [19, 20].

Student voices further allow faculty and students to be empowered with resources to raise the level of academic rigor [21]. Academic rigor is illustrated when students are actively learning meaningful content with higher-order thinking at the appropriate level of expectation in a given context [22]. This level of expectation includes the right graduate attributes which must be demonstrated by students before they enter Industry. Student voices therefore play an important role in determining if ALL the required graduate attributes have been covered in an engineering curriculum.

Listening to student voices can help teachers to reflect critically on their practice to develop policies and practices in the classroom that will more strongly engage students [23]. Student engagement is defined as a two-way street that includes the time and energy students spend on educationally purposeful activities and the degree to which the university gets students to participate in activities that lead to student success [24]. Exposing students to weekly practical work in a laboratory in order to reinforce their theoretical knowledge is considered as student engagement within this study. Obtaining student voices or feedback on this practical work has been effectively used in engineering with regard to new laboratory project designs [25] and in designing a mechanical engineering course for general education [26].

III. CASE STUDY

The module used in this research, Applied Strength of Materials 3 (MSK3), is a compulsory offering or module that forms part of the National Diploma: Engineering: Mechanical qualification, comprising of approximately 24 modules in total. This module is usually offered during the final semester (approximately 14 weeks in duration) of the diploma course and builds on previously acquired knowledge in the field of strength of materials. The purpose of the module is to provide students with a general background of beam theory and to calculate and understand principle stresses and strains in engineering materials. The assessment of the theory is done using a classroom written test, (25% contribution to the semester mark), one main test (40% contribution to the semester mark) and one main final examination. The student's final mark is calculated using 40% of the semester mark and 60% of the final examination. The classroom test covers approximately 20% of the syllabus, while the main test covers 75% of the syllabus with the main final examination covering 100%. The main examination features approximately 40% of applied knowledge, 30% of analysis and 30% of evaluate and design questions.

Four practical assignments (35% contribution to the semester mark) are included in the curriculum to help students to bridge the gap between theoretical and practical instruction. These practical assignments further enable students to exercise engineering judgment and apply it to a practical problem. MSK3 encourages group work where a number of students attend practical sessions together. Table 1 lists the theoretical concepts covered in each unit presented in MSK3, along with a brief description of the practical experiment accompanying the unit. CUT has prescribed ten student graduate attributes which needs to be incorporated into the entire curriculum for the National Diploma. Student competency must be demonstrated with regard to sustainable development, problem solving, entrepreneurship, community engagement, technologically literate, numerate, teamwork, communication, leadership and technical competence. Many of these graduate attributes are assessed in the MSK3 laboratory and are correlated to the practical experiments in the discussion which follows.

The first two practical experiments require students to measure the deflections of a beam under various loads. The experimental results are compared to theoretically calculated results, where after students should comment on the findings and evaluate any discrepancies or similarities. The practical experiments are designed to test the students' ability to work and communicate effectively with others, collect and organize information and perform specific calculations. Student graduate attributes of teamwork, technical competency and numeracy are therefore assessed.

Students are expected to measure the strain on a pressure cylinder (with known dimensions and material properties) under various internal pressures as part of the third practical experiment. The practical experimental results are compared with theoretically calculated results and conclusions should be made with regard to perceived differences and why they exist. This practical experiment is designed to strengthen the students' ability to organize and manage themselves and their activities responsibly while using science and technology effectively. CUT student graduate attributes of numeracy (calculating specific parameters using predefined equations) and technological literacy (in terms of effectively using different mechanical technologies) are hereby assessed.

Table 1: Linking theory with practice in a Applied Strength of Materials laboratory

Key theoretical concepts in the syllabus	**Practical experiments in the laboratory**
Slope and deflection of beams	1. Measure the deflections of a cantilever beam and determine the elastic modulus based on the measured and calculated data 2. Measure the deflection of a simply supported beam and calculate the radius of curvature
Circumferential and radial stresses in thick cylinders	3. Measure the strain in a thick cylinder due to an internal pressure and determine the corresponding principle stresses.
Buckling of struts	4. Measure the deflection for various loads and determine the crippling load for various end conditions

The fourth practical experiment requires students to compare the results of experimental crippling loads with loads theoretically predicted by the Euler equations. A relationship between the experimental crippling loads for the various end conditions is to be determined and evaluated by the students. This practical experiment is aimed at enhancing student's ability to critically evaluate information regarding a given problem, and to communicate this problem effectively to others using mathematical and written communication skills. CUT student graduate attributes of numeracy, communication and problem solving is therefore assessed.

IV. METHODOLOGY

An exploratory case study is employed along with descriptive statistics of the quantitative data. An exploratory case study is ideal for analysing what is common and different across cases that share the same key criteria. Furthermore, it is an appropriate tool to obtain preliminary enquiries [27]. Student voices regarding the benefits, relevance and practicality of the practical work done in a laboratory are sought. Descriptive statistics are used as the results are interpreted with regard to specific African engineering students enrolled at CUT.

Quantitative analysis is used as it brings a methodical approach to the decision-making process, given that qualitative factors such as "gut feel" may make decisions biased and less than rational [28]. The target population is restricted to African undergraduate engineering students enrolled for MSK3 at CUT during 2014 (n = 32). An electronic response system was used in a classroom environment at the end of the semester to obtain student perceptions on specific questions relating to the practical work done in the laboratory. Closed-ended questions, featuring Likert scales, were used based on previous research which focused on student perceptions of practical work done in a laboratory [5, 29, 30].

V. RESULTS AND DISCUSSIONS

The purpose of this paper is to consider undergraduate engineering student voices regarding practical work done in a MSK3 laboratory. This is divided into three sections; one focusing on whether students feel that the practical work was enjoyable and beneficial (see Figure 1); one focusing on whether students felt that the practical work was challenging and relevant (see Figure 2); and one focusing on student recommendations regarding the practical work (see Figure 3).

The results presented in Figure 1 indicate that 77% (42% strongly agrees and 35% agrees) of the 32 respondents to the questionnaire in the MSK3 class really enjoyed the practical experiments which were done in the laboratory. Although 81% (53% strongly agrees and 28% agrees) of the respondents agree that the subject was a valuable learning experience, only 68% (34% strongly agrees and 34% agrees) would recommend the subject to other students. 72% (38% strongly agrees and 34% agrees) of the respondents were convinced that the practical experiments helped them to apply new knowledge to solve engineering problems while almost all students were convinced that the experiments gave them a better understanding of the theory (48% strongly agree and 34% agree). The last two responses are especially important as the graduate attribute of

problem solving and the ability of a student to apply their theoretical knowledge in practice is highly prioritised by ECSA.

Figure 2 categorizes three questions which may be linked to the relevance and difficulty of the practical experiments. Although 48% of the respondents were of the opinion that the practical experiments were not too difficult, the majority (16% strongly agrees and 59% agrees) found it challenging. 96% (73% strongly agree and 23% agree) of the students agreed that the practical experiments were indeed relevant to the theory done in the classroom. Practical work which is relevant to theory and accessible to students, can go a long way towards increasing the enjoyment and sense of achievement of students [33]. It is important for students to 'learn by doing' and it has been found that active student engagement in authentic practical work, which is relevant to Industry, benefits student learning [34]. Subsequently, it may be stated that these results tend to suggest that the practical experiments promoted student engagement with the theory

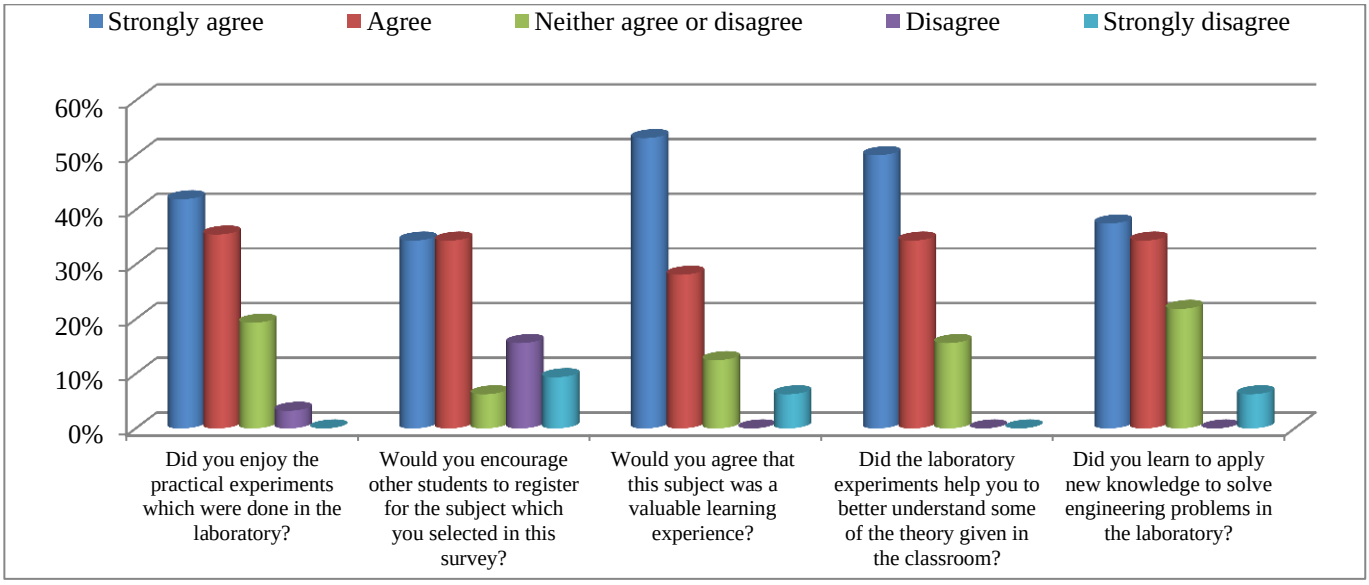

Figure 1: Student voices regarding the benefits of practical work done in the MSK3 laboratory

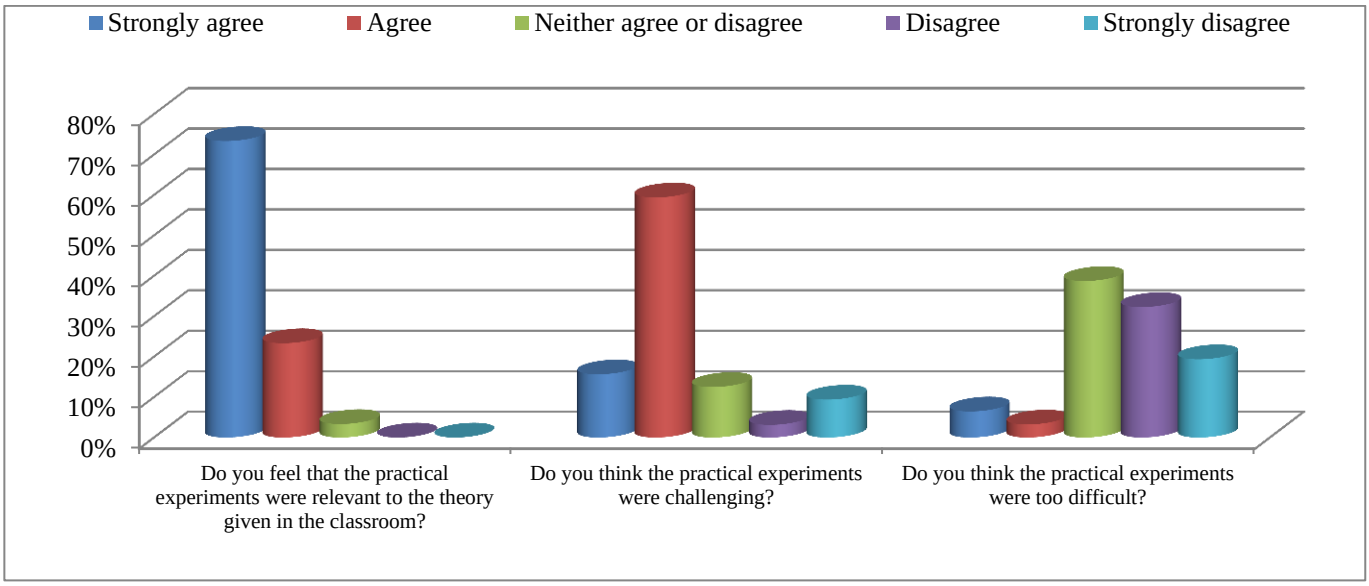

Figure 2: Student voices regarding the relevance between the practical and theoretical work in MSK3

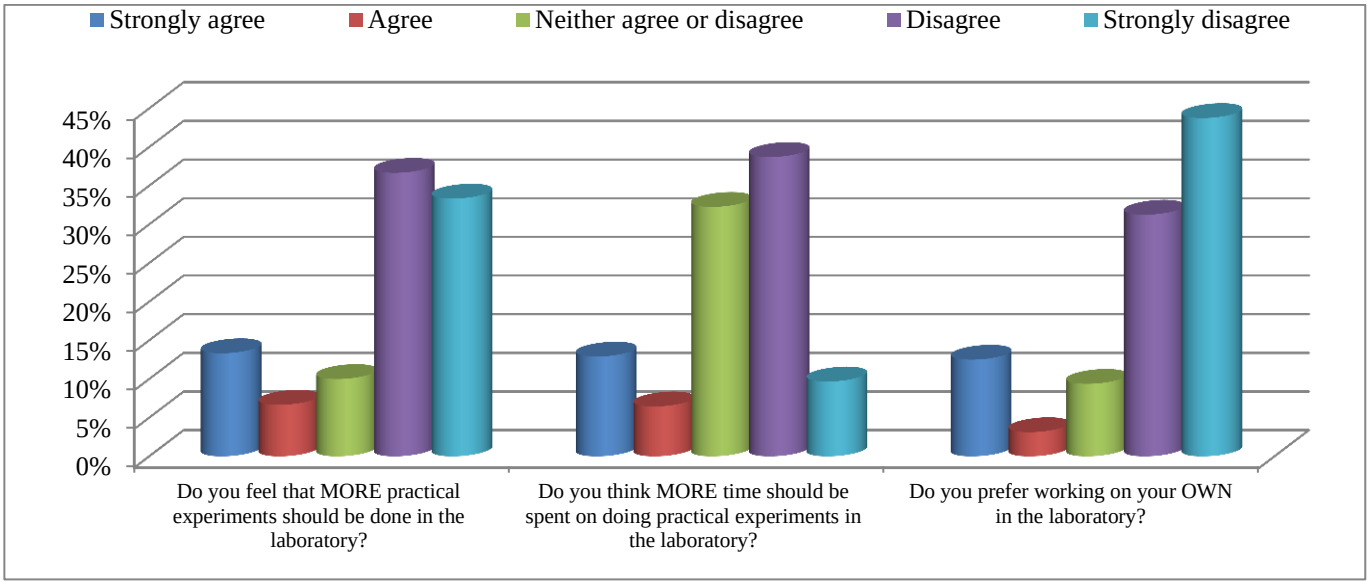

Figure 3: Student recommendations regarding the practical work

From the data presented in Figure 3, it is evident that the majority of respondents felt that the number of practical experiments completed in the laboratory were sufficient (37% disagree and 33% strongly disagree that more practical experiments should be conducted). More than 40% of the respondents were of the opinion that more time should not be spent on doing practical experiments in the laboratory. This is rather a discrepancy when considering the results of the other questions. It may be that students feel that the current timetable which schedules 3 hours per week in the laboratory is sufficient for them to grasp the link between theory and practice. Additional research into why students feel this way is warranted. On the more positive side, 75% of the respondents prefer group work, as shown by the responses to the question of working on your own in the laboratory. This may assist students to develop the important graduate attribute of teamwork, which is advocated by the International Engineering Alliance [35] and based on the Washington, Sydney and Dublin accords.

VI. CONCLUSIONS

The purpose of this paper was to consider student voices regarding practical instruction offered in an Applied Strength of Materials laboratory within the Department of Mechanical and Mechatronics Engineering at a UoT. The specific practical experiments that are currently undertaken by undergraduate engineering students in this field of study were outlined and linked to the specific theoretical sections within the syllabus of this module.

The results indicate that the majority of students enjoyed the practical experiments completed in the laboratory, contributing to student engagement with the course content. The practical experiments were relevant to the theory and applicable in encouraging problem solving, communication and teamwork which are fundamental graduate attributes that engineering students need to demonstrate. These results suggest that student satisfaction has been achieved with the practical work in this module and has led to student engagement as they have devoted time and energy to this educationally purposeful activity.

Additionally, important student graduate attributes of numeracy (calculating specific parameters using predefined equations), technological literacy (in terms of effectively using different mechanical technologies) and technical competency (collecting and organizing technical information) were also assessed in the laboratory (see Table 1). A total sum of seven different graduate attributes have been incorporated into the practical instruction which forms part of this engineering curriculum, thereby giving Mechanical Engineering students the opportunity to demonstrate their acquisition. The successful acquisition or demonstration of these graduate attributes and the indication of student satisfaction and engagement has the potential to empower graduates to enter industry with the ability to contribute to the socio-economic development of their communities and of South Africa.

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Engineering Education for Sustainable Development: Embedded Skills in Problem-based Project-organized Learning

M. Havenga and P. Tolmay

Abstract **- The purpose of the research was to explore whether the application of problem-based project-organized learning in a first-year engineering course could provide opportunities for the development of additional skills to support sustainable engineering and professional practice. A social constructivist approach directed this research and a qualitative methodology was employed, comprising mainly the observation of students during project design and development. It was compulsory that all engineering students (380) enrolled for the generic introductory course. Students were divided into diverse project teams where each team comprised six members. The teams were required to design and develop real-life engineering projects. Preliminary results indicated that the development of embedded skills could support sustainable engineering and professional practice. These skills included student-centered learning, self-directed learning, collaborative learning and teamwork, and metacognitive and reflective skills. Additionally, some recommendations are included.**

Index Terms **- Engineering education, problem-based learning, project-organized learning, skills, sustainability**

Introduction

In a continuously changing world, knowledge that students obtain during their studies at university is not necessarily applicable in industry within five to ten years' time. Darling-Hammond [8, pp. 22] asserts that we need to prepare students "for jobs that do not yet exist using technologies that have not yet been invented to solve problems that we do not even know are problems yet". This challenge is essential when focusing on the development of sustainable engineering education.

Sustainability refers to the ability or capacity of maintaining something over time [25]. The discourse of sustainability may affect change since universities have an important role in supporting the development of future members of society [16]. Hence, this research context of sustainability involved the development of innovative high-quality teaching and learning skills and competencies in higher education over time to enhance professional development in engineering.

Universities are key role players in shaping the future in terms of students constructing new knowledge and developing competencies to address future demands [28]. Garrison and Akyol [11] concur as they mention that there is a shift in higher education to collaborative knowledge construction with the aim to enhance reflective, critical thinking and meaningful learning experiences. Barth and Michelsen [1] support this notion by mentioning that education is considered crucial in the prominent focus of sustainability since it influences educational practices. Although practices such as problem and project-based learning [23] have been implemented in engineering education, Wiek, Xiong, Brundiers and Van der Leeuw [32] are of the opinion that the integration of such teaching–learning strategies is essential in sustainability programs.

Problem-based learning (PBL) is an instructional practice that provides opportunities for solving complex, real-life problems with the aim of developing essential competencies for future demands [12], [15]. Central to PBL is authentic learning where students need to address an ill-defined problem or challenge with no obvious solution [4], [21]. PBL involves a recursive process iterating towards the solution of the problem while using various supportive skills.

PBL can be implemented in various ways, for example it can be organized around the development of a full-scale project, planned and developed over time, which requires a high degree of self-direction [7], [20]. According to Case [4], project-based learning refers to the application of new knowledge based on a problem, as specifically implemented in the final-year engineering project. With the focus on sustainability, we implemented PBL in a generic first-year engineering course to provide opportunities for the development of additional skills from the first year onwards. As part of this initiative, we decided to implement the problem-based project-organized approach [7], [20]. The main research question was: *To which extent can problem-based project-organized learning enhance sustainable development in engineering?*

The rest of the article is structured as follows: Firstly, a summary of the theoretical overview is provided. The subsequent section is devoted to the empirical investigation, preliminary results obtained as well as a discussion thereof. This is followed by the recommendations and conclusion.

Theoretical overview

Sustainability science aims to develop solutions to complex societal problems. According to Wiek, Xiong, Brundiers and Van der Leeuw [32], appropriate skills cannot be developed by using the direct teaching approach mainly. The application of hands-on practice, teamwork and community engagement is required to provide for rich learning experiences. Barth and Michelsen [1] claim that the nature of educational science and sustainability science has two aspects of commonality, namely both are problem-driven by

exploring opportunities for teaching and learning, and both rely on related disciplines. The field of Engineering is mainly problem-driven, as indicated by the first exit level outcome (ELO 1) of the Engineering Council of South Africa (ECSA) where students are required to solve complex engineering problems creatively and innovatively [9]. Integrated in engineering are various disciplines such as mathematics, physics, chemistry and computer science. ELO 2 refers to the application of scientific and engineering knowledge to solve engineering problems.

Sustainable academic programs could benefit from using teaching–learning strategies such as problem- and project-based learning since such approaches are "explicitly problem-driven and solution-oriented" and involve key futures such as student-centered, self-directed and collaborative learning [32, pp. 432]. Carvalho [3] portrays this notion as he mentions that typical learning in PBL involves building on authentic problems by mirroring professional practice, self-directed and student-centered learning, teamwork emphasizing tasks and responsibilities, and reflection about the strategies used. These key features are outlined in more detail.

Student-centered learning refers to students' active involvement in their learning activities rather than filling them with knowledge as passive learners [27]. When implementing PBL, the roles of the facilitator and student differ in the sense that the facilitator is usually responsible for the planning and scaffolding of teaching–learning activities, whereas students participate as strategic, collaborative learners and active constructors of knowledge [14], [32]. The development of engineering projects encapsulates opportunities for students to be active participants and to develop the mentioned skills from the first year onwards.

Self-directed learning involves that students take responsibility for their own learning and that they are accountable for specific tasks, which refers to the self-motivated quest for managing their learning processes [13]. Accordingly, a responsible student is motivated and inspired to perform specific tasks and as a result, he or she is liable for completing such tasks [13]. To portray this notion, Knowles [19] is of the opinion that individuals who take responsibility for their own learning processes learn more and better than those who do not. Similarly, this view underscores exit level outcomes 9 and 10 where engineering students need to demonstrate competence to engage in independent learning and take responsibility within their own limits of competence [9].

Engineering students need to demonstrate competence when working in teams and multidisciplinary environments (ELO 8) [9]. A project team should be managed effectively, which necessitates that members take responsibility and accountability for individual as well as group activities. In addition, teams need to apply effective communication techniques such as active listening, conflict management, collaborative reasoning, decision-making and problem solving [17], [18]. According to Nussbaum [24], collective argumentation is an essential part of student-centered learning environments to enhance conceptual understanding, address misconceptions and support decision-making. Working as a team could enhance the effectiveness of decision-making and problem solving and could also improve group memory since the team benefits from each member's contribution and expertise [30] as they complement each other.

Metacognitive and reflective skills enable students to manage their "knowing" in order to be responsible, independent, dedicated and strategic learners [29]. Metacognition involves the ability to think about our own tasks and strategies, implement processes to direct our own thinking and decision-making, and reflect on all actions performed, with the aim to enhance deep and significant learning [10], [30]. Metacognition addresses two foci, namely knowledge and control. Metacognitive knowledge entails knowledge of a person, knowledge of a task and knowledge of strategies to be used. Metacognitive control refers to managerial processes involved such as planning (goal setting and analyzing of tasks), monitoring (assessing an individual's progress), reflection (reflecting while doing a task and reflecting after completing a task) and evaluation (determining task efficiency) [10], [30], [31].

Consequently, metacognitive thinking enables team members to reflect on previous experiences and current practices to inform future experiences. The Consortium to Promote Reflection in Engineering Education (CPREE) [6] is of the opinion that reflective experiences have always been essential in developing expertise due to expanding the need for diverse and broad thinking in engineering. While PBL has some challenges as an unstructured approach, embedded in it are rich opportunities for the development of essential skills to enhance sustainable development [3], [5], [14].

Empirical research

This subsection outlines the approach, methodology and design used as well as details about the participants and the engineering project.

Point of departure and methodology

A social constructivist approach directed the current research since this approach accentuated critical argumentation, collaborative construction of knowledge and shared responsibility as part of developing innovative engineering projects [22], [24], [26]. We applied a qualitative methodology. This research was part of a larger research project for which ethical approval was obtained.

Research design

The research design involved several supportive activities prior to the intervention as well as a six-month intervention period where the teams designed and developed their engineering projects. The research design is shown in Table 1.

Table 1: The research design used in this study

Facilitate skill development prior to the intervention	Intervention 6 months
-Organize meetings -Self- and peer-assessment of all activities -Theoretical induction (safety and security) -Practical induction (e.g. welding and grinding).	-Project planning: involves scope, time and cost aspects -Project design: includes drawings of the project in Solid Works™ -Project development: requires deliverables such as the project, documentation and poster -Project evaluation and open day: poster session about projects.

Participants

It is compulsory at our university that all first-year engineering students enroll for the generic introductory module. The population consisted of one cohort (N=380) comprising first-year students enrolled for one of the following programs: Mechanical and Nuclear Engineering; Chemical and Minerals Engineering; Electrical, Electronic and Computer Engineering; Industrial engineering; or Electromechanical Engineering.

Selection of 64 project teams (comprising mainly six students in a team) was done according to a personality test. The purpose was to ensure that engineering students would be able to work in diverse teams since such groupings was a reflection of real-life engineering settings. Team members involved both male and female students as well as students who differed in terms of culture and home language. Mentors (senior engineering students) were assigned to teams to support them during all phases of project development.

Engineering project

A project was allocated to a team depending on their priority list of possible (not similar) projects. Lecturers gave facilitation regarding how to conduct meetings, do research, learn about safety and security principles (theoretical induction), compile a work breakdown structure (scope) and Gantt chart (time), compile a budget (cost) as well as how to prepare a project initiation document (PID) involving project requirements for approval. Subsequently, students started working on the design and drawings by using Solid Works™. After approval of a team's budget, they were allowed to purchase the required materials. The students were also supported in practical engineering tasks such as welding and grinding (practical induction). After final approval of the PID and budget, a team was allowed to start developing the practical project in the workshop. Additionally, team members assessed each other on a weekly basis in terms of their involvement in and contribution to project design and development.

Data collection and analysis

Observations were used as data collection method. Students were observed prior to and during the intervention as outlined in Table 1. Observations were written down as narratives and comments to indicate students' involvement in project development. Additionally, we had formal meetings with each team to discuss their concept design and drawings as well as their progress and the problems that they had experienced. We had two formal meetings with each team and thereafter it was the team's responsibility to schedule appointments with the lecturer for additional support as required. During the meetings, we made some reflective notes regarding each team's progress. We analyzed the data manually by identifying main themes as based on the literature overview.

Results and discussion

Preliminary results are outlined as themes, which were based on the literature overview. The themes were the following: student-centered learning, self-directed learning, collaborative learning and teamwork, and metacognitive and reflective skills.

Theme 1: Student-centered learning

Students' active involvement in project development was demonstrated in various group members' participation. Activities of some groups are discussed. Group 7 (G7) designed and developed a multipurpose wheelchair to enable people to use this at the beach. During concept design, all members worked in collaboration. There was active involvement and input when students decided on purchasing the steel. Group 30 designed and developed a hammer mill. Their team actively participated in selecting and purchasing the essential materials. They discussed the type of steel (e.g. strength, diameter) required. Students' involvement in problem solving and decision-making as a team emphasized members' active role in project development. One participant of Group 20 (G20) mentioned, "We had no experience [with problem-based, project-organized learning] and we were required to continuously make plans to manage the project and set milestones."

Both Groups 21 and 24 experienced problems when developing their projects. Some of the members did not actively participate in team work. Regarding these two groups, the lecturer was required to "do more", to support students and directed them during team meetings. Groups 21 and 24 required additional support with regard to their Gantt chart, work breakdown structure, material selection as well as their final planning, design and development. One of the main problems was that these teams postponed their tasks and did not accomplish the milestones in time. In fact, Group 21 did not submit any detailed drawings. Participant 1 (Group 21) mentioned, "We worked against each other instead of doing tasks in collaboration." As a result, they were not able to develop the project and did not pass this course. With additional support, interaction and guidance, four of the members of Group 24 completed the project and passed the course. Groups 7 and 30, instead, reflected active involvement in project development whereas Group 21 and

some members of Group 24 were rather passive learners as mentioned by Pourshafie and Murray-Harvey [27].

Theme 2: Self-directed learning
All team members should direct their own learning activities. Participant 1 (G21) mentioned, "If I am not doing other members' tasks, it will not happen in the group". Therefore, the remaining team members did not accept accountability for specific tasks [13]. Only four members of the team attended a scheduled meeting with the lecturer. Some students were not motivated and, as a consequence, they were not responsible for specific tasks. For example, one of the members in Group 21 did not purchase the wheels. Two members of Group 24 in particular did not take responsibility for assigned tasks and indicated social loafing since they hoped that the remaining members would do their tasks. With regard to self-directed learning, one team member (G20) reflected on his own capabilities and stated, "I had some problems with the drawings … this was not part of my strengths ... therefore each team member needs to support the team in accordance to his [her] strengths."

Possible reasons for not succeeding in their projects were the following: students were not motivated, they mainly focused on formal engineering courses such as mathematics and physics and this practical course was seen as "not so important"; individual members were not accountable and some expected the remaining members to do the tasks. These students did not manage their learning processes effectively as an essential characteristic of self-directed learning [19]. In addition, Bell [2] emphasizes that the development of independent learning may support lifelong learning.

Theme 3: Collaborative learning and teamwork
A noteworthy contribution was the collaboration of the following groups: 7, 8, 9, 29, 48, 50 and 54. They applied their knowledge and supported each other. For example, Group 29 transformed their view from "Can we do this" to "We are able to collaborate and develop the project." Each team member (G29) was assigned to specific tasks that had to be completed on target dates. Members of G20 mentioned that using a Gantt chart supported their project planning in the sense that it directed their team activities towards achieving specific milestones.

However, the majority of students were not used to working in teams and experienced some difficulties regarding their interaction. They required additional face-to-face sessions with mentors and lecturers to support the teams (Groups 35 and 49). Participant 1 (G21) mentioned, "I think we do not understand each other … there is no support." Some team members did not attend formal meetings with the lecturer (G24), did not schedule for a specific time to work in the workshop, and experienced problems with the drawings of the design (G21, G24). Group 20 emphasized, "some team members did more than required to ensure that we obtain high marks, however the other members did not address the tasks assigned to them". General problems with teams involved team management problems, unbalanced team responsibilities, unmotivated students, ineffective communication, and time management problems as a result of the postponement of tasks. Project development was hampered, delayed or unsuccessful in circumstances where the members did not work effectively as a team.

An interesting observation was that some teams did not experience problems with the planning, design and drawings of their project; however, they had problems with the development thereof, which required practical engineering skills. In contrast, other teams had problems with the design though they could easily develop their project.

The teams used WhatsApp, email, Google Drive and e-Fundi (similar to Blackboard) to communicate with each other, manage their meetings and schedule appointments for doing practical work in the workshop.

Theme 4: Metacognitive and reflective skills
This theme involved examples where some teams applied metacognitive and reflective skills and others did not. Group 47 and 54 discussed the "Playground" (swings) with the lecturer. This project involved two teams addressing different aspects of the project. According to the lecturer, their knowledge was insufficient and they were required to visit the community to obtain additional information, for example the age of children using the playground as well as details about specific forces required. Group 11 experienced problems with communication as well as interpreting 2-dimensional and 3-dimensional drawings. To emphasize the role of monitoring and reflection, Group 14 did not address the client's requirement and experienced problems to develop a coffee trolley. After various reflections, they needed to make some changes. Initially, Group 16 had problems with planning and coordination of tasks; however, after they had had team meetings, these problems were addressed. Participant 1 (G21) reflected, "If I am not doing a specific task, it will not happen in the group". An honest reflection of one team member (G20) was, "you do not develop practical skills when working only one evening [in the workshop]". Students need to think about their tasks and reflect on all actions performed to enhance deep and significant learning [10], [30]. Group 50 continuously reflected on their activities, used own initiative and as a result, they completed their project successfully.

Integrated findings and recommendations
This subsection addresses the research question: *To which extent can problem-based project-organized learning enhance sustainable development in engineering?*
Our findings suggest that some students experienced problem-based project-organized learning as a challenge since this strategy was based on an unstructured real-life problem, which required the integration of diverse skills. In addition, there was a shift from individual to teamwork where each member needed to be actively involved in specific tasks (Theme 1). One participant mentioned that they had no experience regarding the PBL approach and were required to make plans continuously to manage the project and address the milestones. This example indicates

that some members were dedicated to complete the project on time.

Nevertheless, some teams had problems with responsibility and accountability as a crucial characteristic of self-directed learning [19]. Team members experienced problems with time management and to some extent the management of their learning processes. Due to additional responsibilities, students mainly focused on mathematics, science and related courses where formal tests and examinations were required since this was not the case with the generic introductory engineering course as the aim there was focused on professional practice (Theme 2).

Moreover, some teams had problems to work in collaboration as they postponed their tasks and relied on other team members to complete the activities. Additional challenges also involved unbalanced team responsibilities, unmotivated students and ineffective communication (Theme 3). As a result, one group (G21) was unable to complete their engineering project.

As part of metacognitive and reflective skills, some groups' knowledge was insufficient (Group 47 and 54). They did not address the client's requirements (Group 14), and teams had problems with management and control (Group 21) (Theme 4). Team members need to be "explicitly problem-driven and solution-oriented" to address real-life challenges [3], [32]. Furthermore, G20 emphasized that skills development can only be attained when working frequently, for example, developing welding and grinding skills.

Findings emanating from this research indicated that, although the PBL approach provided opportunities for deep learning and developing embedded skills required for sustainable development in engineering, most of the teams struggled with this unstructured learning approach.

Some recommendations to lecturers and students to enhance sustainable development in engineering involve the following:

- Integrate teaching–learning strategies such as PBL to enhance sustainability in engineering programs and enhance meaningful learning.
- Scaffold students by teaching supportive skills before starting with the project.
- Maximize team efficiency as part of PBL by implementing cooperative learning, since this type of collaboration may address individual and team responsibility and accountability, enhance social strength and communication, and prevent social loafing.
- Ensure that all team members are actively involved. Develop better group performance and cohesion by means of assigning clear and balanced responsibilities to members with each member's strengths in mind. Work as a team instead of against each other.
- Members are required to assess themselves as well as their peers frequently to determine their progress.
- Direct students' thinking in such a way that they control their mental activities effectively, especially when addressing real-life problems and complex tasks. They need to monitor their activities and reflect on these continuously during project design and development.
- Motivate students to work towards specific objectives, such as developing a project to support the community.

Conclusion

The present study explored to which extent problem-based project-organized learning can enhance sustainable development in engineering. Although the mentioned learning approach mirrored professional practice and provided opportunities for additional skills development, some students experienced problems with self-directed, student-centered learning, collaboration and responsible teamwork, and the application of metacognitive and reflective skills. As reflected from the integrated findings, the weakest link was the inability of teams to work responsibly in collaboration. The required skills should be facilitated and taught to students. Some recommendations were included to address sustainable engineering education.

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Advantages and Short Comings of Using Problem Based Learning in Engineering Education in Uganda

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Abstract **- Education of engineers is very critical to a country as a much needed catalyst for the nation's socio-political and economic development. The major challenge is that most universities in the developing countries at present are not producing enough engineering graduates in terms of numbers and quality. Problem Based Learning has been identified as one of the approaches to producing quality graduates of engineering. However, Problem Based Learning as used in training of other professions has its own advantages and short comings. The purpose of this study was to identify the key advantages and shortcomings of Problem Based Learning in engineering education. A class of 65 that partly uses Problem Based Learning was used in the study and they rated the identified factors. The coefficient of variation was calculated and used to rank the advantages and shortcomings. The major advantages include Problem Based Learning improves retention, recall of information, and it fosters deep learning. The major short comings are that programme implementation is costly and Problem Based Learning overloads students. Stakeholders in engineering education can focus their attention and optimize the resources in the application of Problem Based Learning in order to produce the required number and quality of engineering graduates.**

Introduction

University Education, as it is the case in developing countries has a specific mission of producing a critical mass grounded in the key generic skills. On the basis of high quality higher education, graduate engineers often provide the needed catalyst for the nation's socio-political and economic development. The major issue, however, is that some studies and opinions of experts show that universities at present are not producing high quality graduates as provided in [1]. This contributes to the reasons why most of the developing countries have stagnated in development or have remained stagnant in terms of growth.

Some people have attributed the issue of low quality graduates to the methods and practices used in teaching and learning. The passive teaching of chalk and talk used alone has been highly criticized as a method of teaching and learning at higher levels of education as posited by [2]. It is estimated that more than fifty percent of graduates in many universities in East Africa lack the requisite skills [3].

The fundamental purpose of engineering education is to build a knowledge base and attribues to enable a graduate to continue learning and to proceed to formative development that will develop the competences required for independent practice [4].

Problem-based Learning (PBL) has been defined as "an instructional (and curricular) learner centered approach that empowers learners to conduct research, integrate theory and practice, and apply knowledge and skills to develop a viable solution to a defined problem" as defined by [5]. As pointed out by Prince [6], PBL is an instructional method where relevant problems are introduced at the beginning of the instructional cycle and used to provide the context and motivation for the learning that follows. It typically involves a significant amount of self directed learning on the part of the students.

While PBL has advantages, it also has its own challenges in its implementation. There is a dearth of knowledge in the use of PBL in engineering education particularly its advantages and disadvantages. Many studies have address PBL in other sectors such as human medicine [7]) and agriculture education because it has been used there longer. The purpose of this study was to analyse the advantages and challenges of using PBL as a learner centered approach in Engineering education in Uganda with a view to improving the approach in teaching and learning.

Review of advantages and Disadvantages of PBL

Many authors have made contributions on the advantages and disadvantages of PBL in other disciplines other than engineering. PBL allows students to articulate incorrect knowledge, providing them with the opportunity to revise their false beliefs when confronted with correct knowledge [8]. It contributes towards the reduction of information overload that overburdens many of our students through its identification of core curriculum [9]. PBL develops capabilities: adopting a more universal or holistic approach, awareness (active listening), collaborating productively in groups or teams; it develops generic competencies, i.e. it allows students to develop generic, personal, transferable skills and attitudes desirable in their future practice; and it facilitates an integrated core curriculum [10].

PBL facilitates the relevance of curriculum content, i.e. it structures student learning round common clinical problems [11]; PBL fosters deep learning, i.e. students interact with learning materials [11]; PBL helps distribute the cognitive load among the group members[12]; PBL improves retention and

recall of information [13]; PBL is a constructivist approach, i.e. students activate existing or prior knowledge to identify what they still need to learn and build on existing conceptual knowledge frameworks when generating learning issues [11] ; it is engaging, interesting and stimulating and motivating [8]; it makes the students more responsible for their learning [9]; it promotes students' confidence in their problem-solving skills [11]; and it provides students with scenarios that can be considered by students, in many instances, as prototype cases which can be used as a framework for their learning[9].

Various authors have posited that PBL has its own short comings. It denies staff the fun of sharing their processes of understanding with their students and of getting a buzzout of teaching [9] and it deprives students' access to a particular inspirational teacher (Problem-Based Learning at HYMS, [13]). Other researchers have argued that it disadvantages students educated in a lecture-based and competitively graded environment [14] and it disadvantages the students educationally [15]. PBL is difficult and frustrating for the tutors who cannot "teach" [11] and can be time-consuming for students, particularly if they need to identify educational resources for themselves [14]. Other researchers argue that while it make students unsure about how much self-directed study to do and what information is relevant and useful [13], it requires more human resources (more teaching staff) to take part in the tutoring process and needs more material resources (the same library and computer resources) for the students to access simultaneously [11]). PBL overloads students [13] and programme implementing is costly [9]. It provides no real way of determining if students learn the right stuff [17]; and provides students with knowledge that tends to remain unorganized [18].

Methods

The most common approach employed in obtaining opinions is the survey [19]. Surveys through guided questionnaires were found appropriate because of the relative ease of obtaining standard data appropriate for achieving the objectives of this study.

Listening to what students have to say about teaching and learning is important [20]. The approach was adopted because of its effectiveness in getting accurate information from a group of students with different perceptions about how they are taught and learn.

The study objectives necessitated the identification of the advantages and challenges of using PBL in various areas of higher education. A review of the literature was conducted for the purpose of identifying the advantages and challenges. The researcher identified fourteen advantages of PBL that were applicable to engineering education. Similarly, the challenges were identified and reduced to twelve in number.

The advantages and disadvantages were then formulated into a data collection questionnaire. At the end of the questionnaire, space was left for the students to document their comments on the highly rated factors. The data on strength of advantages and shortcomings of PBL were collected on 1 to 5 Likert scale rating of the strength of the identified factors. [19]. The ratings were 1 – strongly agree, 2 – agree, 3 –not sure, 4 – disagree and 5 – strongly disagree.

Pilot studies were carried out on four students of the same class who were later excluded from the wider survey. This was to ensure the clarity and relevance of the questionnaire to the students. Based on the feedback from the students, minor amendments were made to the questionnaire to remove ambiguities and discrepancies. The draft questionnaire was revised to include the suggestions of these participants before launching the main survey.

The survey gathered data from a class of engineering students who are being taught using PBL in some courses and some other courses were largely taught in other ways. On the 6 courses taught in the first semester of 2015/16, two were handled largely through the PBL approach. Out of a class of 65 students, four were involved in the pilot studies. Therefore, all the other 61 students were targeted. 42 students returned the questionnaires. The advantages and short comings were coded as in Table 1. For purposes shortening the presentation, the advantages and shortcomings are coded as in Table 1 and Table 2 respectively.

Table 1: Advantages of PBL used in the survey

Code	Advantage
P1	PBL allows students to articulate incorrect knowledge, providing them with the opportunity to revise their false beliefs when confronted with correct knowledge
P2	It contributes towards the reduction of information overload that overburdens many of our students through its identification of core curriculum
P3	it develops capabilities: adopting a more universal or holistic approach, awareness (active listening), collaborating productively in groups or teams
P4	it develops generic competencies, i.e. it allows students to develop generic, personal, transferable skills and attitudes desirable in their future practice
P5	it facilitates an integrated core curriculum
P6	PBL facilitates the relevance of curriculum content, i.e. it structures student learning round common clinical problems
P7	PBL fosters deep learning, i.e. students interact with learning materials
P8	PBL helps distribute the cognitive load among the group members

P9	PBL improves retention and recall of information
P10	PBL is a constructivist approach, i.e. students activate existing or prior knowledge to identify what they still need to learn and build on existing conceptual knowledge frameworks when generating learning issues
P11	it is engaging, interesting and stimulating and motivating
P12	it makes the students more responsible for their learning
P13	it promotes students' confidence in their problem-solving skills
P14	it provides students with scenarios that can be considered by students, in many instances, as prototype cases which can be used as a framework for their learning

Table 2: Shortcomings of PBL used in the survey

Code	Short coming
C1	It denies staff the fun of sharing their processes of understanding with their students and of getting a buzzout of teaching
C2	it deprives students' access to a particular inspirational teacher
C3	it disadvantages students educated in a lecture-based and competitively graded environment
C4	it disadvantages the students educationally
C5	PBL is difficult and frustrating for the tutors who cannot "teach"
C6	can be time-consuming for students, particularly if they need to identify educational resources for themselves
C7	it make students unsure about how much self-directed study to do and what information is relevant and useful
C8	it requires more human resources (more teaching staff) to take part in the tutoring process and needs more material resources (the same library and computer resources) for the students to access simultaneously
C9	PBL overloads students
C10	programme implementing is costly
C11	It provides no real way of determining if students learn the right stuff
C12	provides students with knowledge that tends to remain unorganized

Data analysis and results

The analysis of the data was with the help of SPSS 10.0 package and Microsoft Excel. The data collected from the survey were coded and entered into the software that calculated all the required statistics such as mean, variance, coefficient of variation (CoV).

Representatives from participating firms were asked to evaluate the various advantages and short comings of using PBL. Their evaluations were then converted into expected values, variances, and coefficients of variation as shown in equations 1, 2 and 3 respectively.

$$E(x) = \sum_{i=1}^{n} x_i \, p(x_i) \quad (1)$$

$$V(x) = \sum_{i=1}^{n} (x - \mu)^2 \, p(x_i) \quad (2)$$

$$CoV = \frac{\sqrt{V(x)}}{E(x)} \quad (3)$$

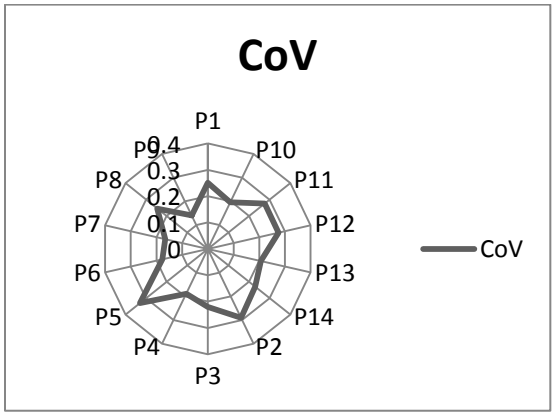
Where E(x) is the expected value of a discrete random variable X; x the values of the random variable for which p(x)>0; p(x) is the probability distribution; μ is the average; V(x) is the variance of a random variable X; and COV(x) is the coefficient of variation.

Table 3: Ranking of advantages of PBL by CoV

Code of advantage	Mean	Std. Deviation	CoV
P1	3.2326	.81174	0.251
P2	3.5581	1.03054	0.290
P3	4.1163	.90526	0.220
P4	4.0698	.76828	0.189
P5	3.1628	1.04495	0.330
P6	4.2326	.75078	0.177
P7	4.3953	.72832	0.166
P8	3.0233	.73964	0.245
P9	4.4651	.63053	0.141
P10	3.8837	.76249	0.196
P11	3.5581	.98325	0.276
P12	3.1628	.87097	0.275
P13	4.0233	.83062	0.206
P14	3.1860	.73211	0.230

Table 3 shows the mean standard deviation and coefficient of variation of the various advantages as coded from P1 to P14. The CoV and the advantages are mapped on the radar diagram as in Figure 1. The lowest CoV indicates greatest significance[21].

Figure 1: Radar diagram of CoV and advantages of PBL



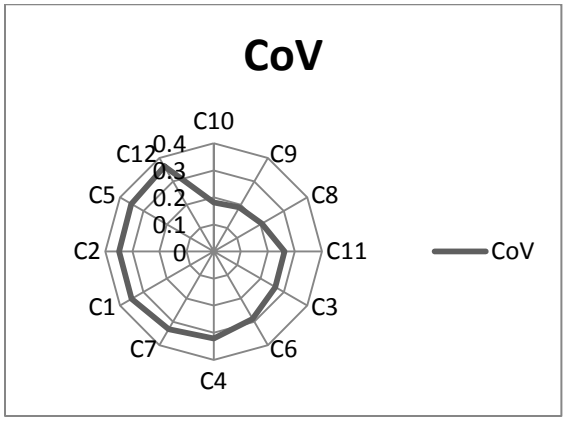
From Figure 1, the four biggest advantages of using PBL in teaching and learning are: PBL improves retention and recall of information (P9), PBL fosters deep learning, i.e. students interact with learning materials (P7), PBL facilitates the relevance of curriculum content, i.e. it structures student learning round common clinical problems (P6) and it develops generic competencies, i.e. it allows students to develop generic, personal, transferable skills and attitudes desirable in their future practice (P4).

Table 4: Ranking of short comings of PBL by CoV

Code of short coming	Mean	Standard deviation	CoV
C1	2.2791	.79659	0.350
C2	2.2093	.77331	0.350
C3	2.6279	.69087	0.263
C4	2.4884	.79798	0.321
C5	2.4186	.85168	0.352
C6	2.8372	.81446	0.287
C7	2.3721	.78750	0.332
C8	4.0233	.83062	0.206
C9	4.0000	.75593	0.189
C10	4.1860	.76394	0.182
C11	3.5581	.93356	0.262
C12	2.2326	.81174	0.364

Table 4 shows the mean, standard deviation and coefficient of variation of the various shortcomings as coded from C1 to C12. These are mapped on the radar diagram as in Figure 2.

Figure 2: Radar diagram of CoV and short comings of PBL



From Figure 2, the four greatest shortcomings of using PBL in teaching and learning are: Programme implementation is costly (C10), PBL overloads students (C9), it requires more human resources (more teaching staff) to take part in the tutoring process and needs more material resources (the same library and computer resources) for the students to access simultaneously (C8) and It provides no real way of determining if students learn the right stuff (C11).

Discussion

The advantages and challenges were ranked using their respective COV. Using COV in ranking has been used before and is considered more reliable than the mean rating alone because it considers both the expectation and the variance [21]. The students commented that PBL improves retention and recall of information. When they handle the problems and get solutions, they tend to remember what they learn even after so many years. This is in agreement with the findings of [6]. The other key advantage that students pointed out was PBL fosters deep learning. Students interact with learning materials and hence find out some of the key principles themselves. This facilitates deep understanding rather than rote surface learning. This is in agreement with the findings of [6]. Students and graduates of engineering are better able to internalize the topics they will have learnt through PBL.

Students commented that PBL facilitates the relevance of curriculum content. PBL structures student learning round common problems in the engineering profession. The research in [7] similarly found that students were able to explore more issues around the common problems.

It was noted that PBL allows students to develop generic competencies. PBL allows students to develop generic, personal, transferable skills and attitudes desirable in their future practice. Some of them include teamwork, technical writing, research to mention but a few.

On the side of the shortcomings, the students regarded PBL as expensive. Most of the students are privately sponsored. Worse

still, there were no loan schemes. Even when they are government sponsored, the sponsorship is exclusive of the transport, materials and other resources used in PBL. Students are in a way forced to pay more towards facilitating the learning process.

The students commented that PBL overloads the students. This was partly because PBL is used alongside other approaches of teaching and learning. PBL works best when it is used across the majority of courses in a semester on a particular programme. When it is mixed with other modes of delivery, it tends to overload the students [6].

The students noted that PBL requires more human resources in supervising the projects carried out by the students on a group by group basis. This is unlike the non-participatory traditional teaching where one lecturer stands in front of the class and conveys the message to all students at a go.

The other disadvantage the students commented on was the perception that one could not easily determine whether the students had grasped the ideas. In PBL, one cannot easily set a uniform standard test for all students because the way problems are handled varies from group to group. There may be free riders in the group as well.

Conclusions

To the fraternity in engineering education, this study presents the advantages and short comings of PBL in engineering teaching and learning as perceive by students. This study can be useful to the practitioners in different ways. First by identifying and evaluating the advantages of PBL, engineering educators can focus their attention and optimize the resources on the real issues. Second, by assessing the short comings associated with PBL, educators can tackle the biggest first. Additionally, engineering educators can use the priority list that includes the advantages and short comings to enhance their chances of successfully training engineers with more practical skills. Moreover, the study sets the foundation for further analysis of each of the advantages and shortcomings of PBL in engineering education. This will enable engineering schools to get more insights and better chances of using PBL so that they produce engineers who are practical and able to make a difference in the societies they serve after graduation.

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Developing and Teaching a First Year Professional Communication Course at an Engineering School in South Africa

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***Abstract*— Currently communication skills are seen as one of the crucial soft skills that a graduating engineer should possess, and governing bodies of engineering activities, such as ECSA in South Africa, give strict guidelines on what they require that these skills should entail. This paper firstly gives some background on the ECSA requirements regarding Exit Level Outcome 6 for professional and technical communication and then focuses on the developing and teaching of a first year professional communication course for the Faculty of Engineering at Stellenbosch University.**

I. Introduction

One of the most important graduate attributes and professional competencies recognised by universities today is the skill to communicate effectively. This need for skills in professional communication has also been identified by the governing bodies of several professional fields, such as the corporate and engineering worlds.

In various surveys conducted on the skills required by business graduates, written communication is always included in the top skills needed ([1]; [2]; [3]). In a recent research project, Margheim, Hora and Pattison [4] asked the partners of mid-sized certified public accountant firms in the United States to identify the most important competencies considered in promotion decisions. Although technical competency was highly rated, the need for effective communication skills was given a higher rating for positions higher up the corporate ladder. Even former dean of the Harvard Business School, Robert Kent, has been known to say "In business, communication is everything."

In the engineering sector, governing bodies across the world have included communication as one of the "soft skills" a graduating engineer should possess. Consequently they argue that the teaching of these skills should form part of engineering programmes at tertiary institutions. This should come as no surprise, because various surveys have shown that engineers are increasingly becoming aware of the fact that they spend between 20% and 40% of their time writing and that in most cases graduating engineers lack the skills necessary to communicate effectively in a professional environment [5]. George Heilmeier [6], who was

involved in developing the liquid crystal display technology and was later CEO of the Bellcore Corporation is quite clear about an engineer's need for communication skills: "Communication skills are extremely important. Both written and oral skills are often ignored in engineering schools, so today we have many engineers with excellent ideas and a strong case to make, but they don't know how to make the case. If you can't make the case, no matter how good the science and technology may be, you're not going to see your ideas reach fruition."

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In this paper we firstly discuss the context for a first year professional communication course at a South African engineering school with reference to the requirements of engineering professional bodies such as the Accreditation Board for Engineering and Technology (ABET) in the United States and the Engineering Council of South Africa (ECSA). Then we look specifically at the development of such a course at Stellenbosch University over the past 12 years.

II. Professional Communication Training – Building Up to ECSA Exit Level Outcome 6

In their criteria for engineering programmes the Accreditation Board for Engineering and Technology (ABET) in the United States specifies that students should be able to demonstrate the "ability to communicate effectively" [7]. However, their South African counterpart, the Engineering Council of South Africa (ECSA), as well as the International Engineering Alliance [8], add another dimension to this skill.

The learning outcome for ECSAs exit level outcome 6 for professional and technical communication states:

*The graduating engineer has to demonstrate competence to communicate effectively, both orally and in writing, with **engineering audiences and the community at large.*** (Our emphasis)

According to ECSA [9] a successful candidate must meet the following associated assessment criteria which must, for written communication, be evidenced by:

1. The use of appropriate structure, style and language for purpose and audience;
2. The use of effective graphical support;
3. The application of methods of providing information for use by others involved in engineering activity;
4. The meeting of the requirements of the target audience.

And for oral communication by:

1. The use of appropriate structure, style and language;
2. The use of appropriate visual materials;
3. A fluent delivery;
4. The meeting of the requirements of the intended audience.

Further clarification is given by the so-called range statement which sets out in more detail the specific communication skills that students should be comfortable with:

- Material to be communicated is in an academic or simulated professional context.
- Audiences range from engineering peers to management and lay persons.
- Appropriate academic or professional discourse is used.
- Written reports range from short (300 to 1000 words plus tables and diagrams) to long (10 000 to 15 000 words plus tables, diagrams and appendices), covering material at exit level.
- Methods of providing information include the conventional methods of the discipline, for example engineering drawings, as well as subject-specific methods.

In a survey done by the highly rated American Society for Mechanical Engineers (ASME) in 2011 [10] communication skills are rated by 1200 practicing engineers as one of the key skills that engineers should have. Interestingly they made a distinction in the survey between business writing skills and technical writing skills, and engineers' need for business writing skills was rated as more important than their need for technical writing skills.

III. Development of a Professional Communication Course for the Faculty of Engineering at Stellenbosch University

In 2004 the Faculty of Engineering requested the University's Language Centre to develop a professional communication course for all first year engineering students, starting in the second semester of 2005. Since 2006, this course has been presented in the first semester of the first year.

From the outset, the team involved in the development of the course kept ECSAs outcomes and range statements as points of departure. However, we kept in mind that this is only a first year course and the Faculty of Engineering does not claim the stated exit level outcomes regarding communication skills in their ECSA accreditation for this course. They do, however, claim it as part of the required complementary studies.

We therefore had relative freedom to decide what would be included in the course, bearing in mind the practicalities and limitations at first year level. A big consideration was also the size of the class and the availability of lecturers. The number of students in the class has gradually been growing from about 300 in 2005 to nearly 800 in 2016. We decided to focus on developing the students' skills at an introductory level so that they would be able to refine these skills as they continue through their years of undergraduate studies.

An important role player in all our decisions was of course the Engineering Faculty itself and what professional communication skills they feel that their students would need right from the start of their engineering studies. In collaboration with the Faculty we therefore decided that the course would focus on the writing of a technical report because this would be the document type most relevant for students during their studies as well as for their future professional lives. Even though oral communication skills are also important for an engineer, we decided that doing something meaningful in that regard would not be practical, even for a class of 300, as it was at the beginning.

In 2015 the Faculty revised their first year programme. As a result, the credits for the professional communication course were reduced from 12 to 8. However, in a discussion with a special task team of the Faculty programme committee we revisited the skills that they want their students to gain from a professional communication course. This discussion confirmed that the Faculty still wanted the technical report to be the main assessment component. However, the need for other communication skills was also mentioned, for example, the engineering student's ability to work as a team member, to be part of an effective meeting and to write the minutes of such a meeting. The Faculty also requested that we begin to introduce students to well-written engineering texts at this early stage of their studies.

IV. Theoretical Background for a Professional Communication Course

In addition to the requirements of the professional body (ECSA) and the needs of the Faculty, we also looked at our own field of study, namely document design and professional and business communication. From this field, two perspectives, which incidentally correspond well with the stated requirements from the engineering side, were taken into account in the development of the content of the course.

Firstly, the genre theory was employed to define the type of writing that would be expected of an engineer in the workplace but also of an engineering student. According to the genre theory ([11]; [12]), genres help us to navigate the complex world of written communication and symbolic activity, because in recognising a text type we recognise many things about the institutional and social setting, the activities being proposed, the roles available to writer and reader, the motives, ideas, ideology, and expected content of the document, and how this relates to the overall context. A course in professional communication for engineering students would then have to introduce the students to the typical conventions, styles and documents and challenges inherent to their specific environment.

Secondly, a common denominator in the genre of engineering writing, as also stated in the required outcomes of ECSA, is the aim to communicate information not only to engineering audiences but also to the community at large. This awareness of writing for a specific audience was then the second perspective taken into account in the development of the course.

V. From ECSA Outcomes and a Theoretical Framework to a Professional Communication Course for First Year Engineering Students at Stellenbosch University

In the following section our professional communication course for first year engineering students at Stellenbosch University is described. Throughout the twelve years in which we have been presenting this course, our aim has been to improve the course every year while always keeping our general point of departure in mind: the outcomes required by ECSA and the theoretical framework for professional communication as set out in the previous section.

From 2005 to 2016 our throughput rates for the course have been consistently between 90 and 95 percentage points. This high percentage can in part be attributed to the high selection criteria for acceptance at the Faculty of

Engineering. A new student is required to have achieved an average of at least 70% in the school final examination. In most cases a student who has achieved this average also has good language skills.

A. Outcomes of the Course

The specific outcomes of the module are:

- Identify the aims of communication
- Communicate with different target audiences
- Distinguish between different text types
- Use text types appropriately and effectively
- Design and formulate coherent texts
- Plan and write various documents, with a special focus on the technical report
- Use appropriate referencing norms

B. Design of the Course

As this course is compulsory for all first year engineering students we work with a large group every year, and the numbers have increased substantially, from 350 in 2005 to 750 in 2016. For teaching purposes the students are divided into four groups depending on the language of instruction with two Afrikaans groups and two English groups in 2016. We emphasise it to our students that we are not teaching them a specific language but how to use language as a tool for communicating in their chosen professional field. We often find that Afrikaans students who write their first year reports in Afrikaans, prefer to write in English in their further years of study. They simply transfer the skills for writing in Afrikaans acquired in their first year to writing in English.

1) Introduction to the Engineering Profession

For a number of years now a component was included in the first year engineering programme which focused on introducing students to issues relating to studying engineering at tertiary level. It also introduced them to the various disciplines in the field of engineering, as it is represented by the five departments in the Faculty, namely process, civil, industrial, mechanical and mechatronic, and electrical and electronic engineering. As this content fits in very well with our approach where we aim to introduce the students to the world of engineering through the genre of engineering writing, we decided, in collaboration with the Faculty, to incorporate this content in our course.

Since 2011, this content is presented by lecturers from the Faculty of Engineering as part of our course. Students are introduced to the various engineering disciplines by members of the Faculty, but they are also exposed to guest lecturers from the industry. In addition, the students are given guidance on how to survive as an engineering student.

We find this component to be a crucial part of the training we need to give students to become part of the broader professional engineering environment, especially as our student population is getting more and more diverse, and we have a growing number of students with no previous contact with the engineering profession. Pierre Bourdieu [13] used the term cultural capital to define a resource transferred over generations and possessed by families and individuals that equips individuals with knowledge, practical skills and a sense of the "rules of the game" of a particular environment. A specific focus on developing the cultural capital of first year engineering students could then contribute to an individual's educational success and more effective assimilation into the professional engineering environment.

2) The Theory of Writing in a Professional Environment

The theoretical aspects of writing in a professional environment with specific attention to the genre of engineering writing are presented by lecturers based in the Language Centre. In these lectures (one per week) the focus is mainly on the building blocks for effective writing such as identifying the target reader and the communicative objective of a specific document, appropriate writing styles for the professional environment, and achieving coherence. We apply these theoretical principles to the various documents that are common within the genre of engineering writing, such as reports, proposals and various forms of correspondence.

At the end of the semester the students write one test which focuses on the theoretical content of the course. Our approach, however, remains on the application of the skills and not on merely giving back knowledge. In the test we would, for example, give a short text for which the students would have to identify, with motivation, a target audience and a communication objective. We would also use the same text to test their understanding of various aspects of professional writing style and coherent writing.

3) Developing Reading and Reading Comprehension Skills

A valuable skill for anyone in a professional environment is the skill to read effectively. This efficiency can be characterised both by reading speed and comprehension. Since 2015, at the request of the Faculty, we have incorporated an on-line reading and comprehension program as part of our course. The full program consists of twenty on-line lessons that students have to do in their own time. The aim is for students to reach a reading speed of more than 250 words per minute and a comprehension of more than 70% - which is considered a first year reading level.

4) The Technical Report

In the course students are introduced to various document types, but for assessment purposes the course focuses on the writing of a technical report. The report counts for 55% of the final mark.

In the choice of a topic for this report, we decided to give students topics that would not only be relevant in the engineering environment, but also relevant in the South African context. In the twelve years that the course has been presented, various topics regarding the need for energy in the world, but also in South Africa, have therefore been set. Even though students are required to gather information on a specific topic, the aim is not to develop their research or information gathering skills. The main aim is to give them the skills to write the report. We therefore make sure that information on the chosen topics is readily available.

The report assignment is formulated in such a way that some information of a more technical nature is required. However, the assignment also specifies that the intended audience for the report is a first year engineering student. The technical content provided should therefore be appropriate for this audience. For example, the report about biodiesel as a source of energy had to include an explanation of the basics of the manufacturing of biodiesel, and the report on a sustainable and renewable energy source had to include

a section on the production of electricity by means of the specific source.

When we started the course in 2005, students had to submit one technical report at the end of the first term. For a student to complete the assignment successfully, a mark of 60% or more had to be achieved. We stressed that 60% would not be acceptable in a professional environment but for our course a mark of more than 60% demonstrated that the student had the basic skills to write a report. Students who received less than 60% had to submit an improved version at the end of the semester.

We changed this system in 2009 because we wanted all the students to have more practice in writing. All students now have to write two reports, a Report A and a Report B. Report A is due at the end of the first term and has to contain all the required sections of a report. This report is then marked and detailed written feedback is provided. Report B is due at the end of the semester, with some additional content, and with an abstract, an introduction and a conclusion that reflect the added content.

The typical information required for the two reports is illustrated by the technical report assignment for 2016. For Report A, students had to discuss, in the body of the report, the following aspects in 1400 words:

- A short overview of energy sources in the world that are suitable for the generation of electricity
- A more detailed description of nuclear energy and an appropriate explanation of the process by which nuclear energy is converted into electrical energy
- A discussion of the advantages and disadvantages of using nuclear energy for the generation of electricity
- **Plus** a *general* conclusion on the suitability of using nuclear energy for the generation of electricity.

In Report B the same three aspects as for Report A had to be discussed, but in addition it also had to have a section on the use of nuclear energy within the South African context. The conclusion for the Report B then had to focus on the suitability of nuclear energy as a source of electricity for South Africa. For Report B the number of words is increased to 2000.

5) The Practical Tutorial Sessions

In addition to the more theoretical lecture, students are required to attend 11 tutorial sessions. The time slot available for these tutorials is three hours on a Monday afternoon. Because of the large number of students, we decided to present the tutorial in two sessions, with students evenly divided into eight tutorial groups. Each group then has a tutorial session of about eighty minutes. Even though these are still large groups to work with, it is more manageable and enables students to engage in discussions about the work and to complete small group tasks. Our aim for the tutorial session is to be a practical class despite the large number of students in attendance.

In the beginning of the year each student receives a booklet, containing the instructions for all the written assignments, as well as examples and exercises to be discussed and completed during the tutorial periods. The topics covered in the tutorial sessions echo the themes in the main lecture. For example, if the main lecture dealt with coherence or paragraph structure, students would complete practical writing exercises on the same topic in the tutorial.

A very useful tutorial tool is the so-called sample report. We start with the incomplete version of this report and gradually build it up until it includes all the components of a report. Initially, in the tutorial booklet, the students are provided with only the title and the body of the report - all the body content is there but no table of contents, abstract, introduction or conclusion. It does have the numbering for the various sections, subsections and sub-sub sections, but none of the headings is provided.

The student's first task is to read through the content and fill in the headings and subheadings as dictated by the content of the specific section or subsection of the sample report. After we have discussed the requirements for the introduction of a report, these headings and subheadings can then be used to write the introduction for the sample report during the tutorial. In the same session, the students are given the opportunity to self-assess their introductions for the sample report and a model introduction is displayed and discussed. The students are then given the instruction to write the introduction for their own technical report for homework.

The same procedure is used to familiarise the students with the requirements for the abstract and conclusion. It has worked well to let the students write the conclusion and the abstract for the sample report in groups of two, where one writes the abstract and the other the conclusion. They peer review each other's efforts to determine whether the abstract and the conclusion can be identified as being two sections of the same report.

After all the sections of the report have been dealt with, the complete sample report is made available to the students on our e-learning platform. The complete report also demonstrates the use of graphics in a report as well as the application of referencing. The report is provided in Word format so that students can use it as a template for their own reports.

6) Assessment of the Technical Report

The two versions of the technical report are assessed as separate assignments. As mentioned in the previous section, Report A is due before the end of the first term. These reports are then marked according to a fixed rubric with the following categories:

- Content (20 marks)
- Use of language (15 marks)
- Professional writing style (15 marks)
- Structure and logical organisation (25 marks)
- Referencing (10 marks)
- Technical presentation (15 marks).

Each marked report has a marking grid page attached to it. This marking grid has the criteria for each one of the categories set out, as well as space for the marker's general comments for a specific report.

For a number of years now we have also been using a list of codes for very specific comments. We developed these codes because we found that we would have to write a comment such as "divide in subsections only if there are more than one subsection, e.g. only a 2.1 if there is also a 2.2" in numerous reports. Now we have a list of numbered

comments, available on our e-learning platform, and where applicable we give only the encircled number and the student has to check the list for the meaning.

As can be seen from the distribution of the marks for the different categories, the largest percentage of the final mark is taken up by the categories "content" and "structure and logical organisation". Although good grammar and spelling is an essential part of good writing, our focus in this course is more on effective communication within the genre of engineering writing. The assessment of the technical report is therefore primarily based on whether the writer has answered all the reader's questions and expectations and whether the report conforms to the conventional structure of a technical report.

The students receive their marked reports back about four weeks before the end of classes for the semester. They then have the time to add the new content, but they can also use the comments on Report A to improve the report before submitting Report B. In essence then, Report B consists of a (potentially) improved version of Report A with some new content added, with an updated abstract, introduction and conclusion. At the end of the semester Report B is submitted, accompanied by Report A, giving the marker an indication of whether the feedback from Report A was indeed taken into account.

At the improvement stage of the report writing process the Writing Lab of the University forms part of the intervention. To prepare the Writing Lab consultants we have a briefing session with them beforehand where we do an assignment analysis and make sure that they are familiar with the requirements for a technical report.

Students who have received less than 50% for their reports must attend compulsory Writing Lab consultations, whereas students with marks of more than 50% have the option to do so. During the consultations students have the opportunity to discuss their own writing with the consultants and also get help in applying the suggestions and comments made by the markers of the reports

Students also have several other options for additional help to improve their reports. If time allows, we schedule question and answer sessions during class time or over lunch breaks where any student can come with questions.

7) Additional Tasks

Group Work and Gaining Knowledge within the Engineering Environment

In the discussion with the Faculty in 2015, we decided to develop an additional assessment task where we would combine the reading of texts dealing with topics in the engineering environment, with group work. The Faculty took the responsibility to provide at least ten appropriate texts.

For the assignment students have to work in groups of five and each group has to read five of the texts. A group must have two meetings and write the minutes for these meetings. Each group must then produce the following documents:

- The minutes of the planning meeting in which the group decides which five texts they will read and which group member will read which text.
- The minutes of the feedback meeting in which each group member has to give feedback on the text that he/she has read.

As feedback each group member must answer the following questions about the text that he/she has read:

- What, in short, is the bigger field of engineering to which this text belongs?
- What is the focus of this particular text?
- Is the writing style used in this text appropriate? Why do you say so?
- Is the organisation of the information in the text effective? Why do you say so?

Writing for Different Audiences

One of the criteria in ECSA Outcome 6 is the ability of an engineer to communicate with the broader community. For the technical report we have chosen a first year engineering student as the target audience. To give the students some practice in writing for another audience we have added an assignment which requires that they rewrite the more technical section of their reports as a short article for the newspaper of a primary school with a reader audience at a Grade 7 school level.

VI. Further Involvement in Professional Communication Training at Stellenbosch University's Faculty of Engineering

Since we started teaching the professional communication course in 2005, we have also become involved in the report writing activities of engineering students in their later years of study. We have input in various ways in the writing of laboratory reports, vacation work reports and final year project reports for the second to final year undergraduate students of the Faculty. This involvement gives us the opportunity to track the development of the students' report writing skills as they have developed from the first year. We also see how and where we can improve our offering in the first year.

We find that the students take the report writing more seriously as they progress in their studies. They have a better sense of the importance of effective communication. Whereas we create a fictitious scenario in the first year, in later years, especially at the final project report stage they experience the reality of writing about their project for a real, informed audience (external examiner).

VII. Conclusion

In 2005 when the professional communication course was first introduced we as lecturers were often confronted by students questioning the need for communication training for engineers. However, since then the attitudes of students have gradually been changing. In our end of semester evaluation by students in 2015, for example, the percentage of students indicating a medium to high level of interest in the course improved from 30% at the beginning of the course to 42% at the end of the course. In a small way this demonstrates that some students are seeing the value of acquiring professional communication skills.

We have also been experiencing a growth in cooperation with our colleagues from the Engineering Faculty who teach the technical content of the programme. It remains a challenge for both parties to find a practical and workable way for content specialist and writing specialist to have an input in the technical documents that students have to generate.

In the Language Centre we are very well placed to prepare the engineering students for the communication challenges that await them in the professional and corporate world. We have the opportunity to work in both the professional and the academic worlds and we can transfer the knowledge and experiences gained in the professional world to our students.

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A Comparison of Teaching Practices at Some Leading Engineering Faculties

Anton H Basson

***Abstract*— Radical changes in university education are regularly predicted, often stated as a fact. Some of these changes relate to the teaching practices. This paper presents observations at six institutions (one in Belgium and the remainder in the USA) of a selection of aspects of their current teaching practices. This study shows that some aspects of teaching practices have changed in recent years, with the increased use of project based learning and the limited introduction of elements of blended learning the most noticeable trends. However, the study found that the classical teaching format of lectures plus tutorials is the dominant teaching practice at all engineering faculties included in the study. Regular (often weekly) formative assessments, which are marked by teaching assistants, are widely used in all the institutions at undergraduate level. In a majority of undergraduate courses, the largest part of students' final marks is determined by one assessment at the end of the semester and, in many cases, one or two major assessments during the semester. This study also shows that a common start to the mainstream engineering programmes, of at least two common semesters, is more of a rule than an exception. The limited sources of data on which this study is based, should be noted. However, the similarity of the results between the institutions surveyed does contribute to the confidence one can have in the conclusions drawn.**

***Index Terms* - Engineering curriculum, blended learning, project based learning, assessment**

I. INTRODUCTION

Radical changes in university education are regularly predicted, often stated as a fact. Some of these changes relate to the curriculum content (e.g. [1]), while many focus on teaching practices. Such claims could create the impression that an institution would be "left behind" if does not introduce radical changes. It is difficult to assess the authority of these claims when many of them are from persons that rely on a platform of university change, or rely on inputs from such persons.

Since I had the opportunity during a sabbatical to visit a number of leading institutions that offer engineering programmes, I used the visits to gauge the current state of teaching practices in engineering faculties/schools/colleges at KU Leuven, Pennsylvania State University, Rensselaer Polytechnic Institute (RPI), Massachusetts Institute of Technology, Harvard University and University of Michigan. This paper presents the main findings of the visits. One hould keep in mind that teaching practices are not static, but are continually changing. External stimuli to these changes, such as the recent NSF call for proposals for "REvolutionizing engineering and computer science Departments (RED)" [2], can have a significant influence. This paper considers the teaching practices in September and October 2015.

The focus in this study is on espoused and enacted beliefs. The question remains to what extent the results correspond to the experience of the students.

II. LITERATURE

It would not be feasible to review all the literature relevant to changes in the practices of teaching engineering, due to the extensive body of literature. This literature review therefore primarily aims to situate this paper's contribution. The review also includes some relevant recent work from the institutions used for comparison.

Henderson, et al. [3], give a useful classification of change strategies, as illustrated in Fig. 1. They distinguish four main categories that change strategies aim to influence: curriculum & pedagogy, reflective teachers, policy, and shared vision. They also placed the four categories in a two-dimensional space, as shown in Fig. 1, using a horizontal axis that moves from prescribed to emergent and a vertical axis that moves from environments & structures to individuals. The horizontal axis indicates whether the intended outcomes of the change strategy is clearly defined at the outset (prescribed) or will develop as the change strategy is implemented (emergent), while the vertical axis indicates the part of the educational system that is targeted.

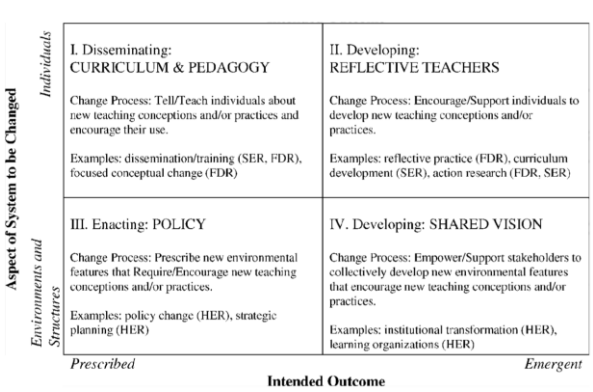

Fig. 1. Overview and conceptual underpinnings of the four categories of change strategies [3]

Recently studies [4] [5] applied the above classification in considering, respectively, the views of engineering education leaders in the USA and strategies to increase the use of evidence-based teaching. The present paper focusses on the first category, i.e. curriculum and pedagogy, with greater emphasis on pedagogy.

Another view [6] is that four structural elements should be considered during curriculum renewal: curriculum content, learning approaches, assessment practices and evaluation practices. The first three are included in this study, with the emphasis on the second and third.

One of the often promoted teaching strategies is project based learning (PBL), which in engineering is normally associated with group work. Successfully implementing these strategies in large classes presents various challenges. One of these challenges is having sufficient tutors to lead the

groups. Van der Hoeven and Peeters [7] presented a useful "coaching model", developed at KU Leuven, which can be used to train tutors to support students in this context.

Another trend in engineering education has been the increased focus on the use of multidisciplinary teams. McNair et al. [8], from RPI, offer some useful perspectives in this regard, considering aspects such as faculty team identity, interdisciplinary pedagogy, valuing diversity, conflict and integration.

The potential risks in introducing teaching innovations are ever present. For example, Fredriksen [9] reports a case where a teaching innovation, that follows ideas often mentioned in current literature, had resulted in poorer learning. Finding examples of successful innovation is therefore important, as well as carefully identifying what the critical success factors are, because a partial implementation of an innovation can do more harm than good, as Fredriksen's case demonstrates.

III. Research Question

This paper is aimed at assessing the validity of claims that radical changes in teaching practices have occurred in recent years in engineering education. The research question has been formulated to provide a scholarly basis for some key aspects of changes in the BEng programmes of Stellenbosch University's Engineering Faculty. The research question is therefore: *What are the current teaching practices at some leading institutions in Europe and the United States, in engineering programmes similar to the BEng programmes offered at Stellenbosch University?* The term "teaching practices", as used here, is taken to focus mainly on the following aspects:

- The aspects of curriculum structure that have strong effects on pedagogy, e.g. the number and placement of project/group work courses. These aspects are of interest because much has been written about the value of increased PBL. However, the resource implications (e.g. staff time, meeting spaces, laboratory or workshop facilities, etc.) are often daunting for large class groups.
- The spectrum of pedagogical approaches used, as well as the fraction of courses that use the different approaches and the placement in the programme of the approaches; for example, the prevalence of the traditional lecture & tutorial format, compared to flipped classroom; or the blended learning approaches are applied, as well as how frequently and where in the programme/curriculum. The growth in the "educational technology" industry has been accompanied by many claims about the advantages of such technology, as well as that the use of such technology will soon be ubiquitous.
- The formative and summative assessment practices applied, as well as the fraction of courses that use the different approaches and the placement in the programme of the approaches. For example, are formative assessments (such as homework or short tutorial tests) given weekly in courses, and does the pattern of these formative assessments change from first to final year courses? This aspect is important because of the well-known strong influence of formative assessment and feedback on students' learning, counteracted by the amount of staff (or teaching assistants) time required to compile and grade formative assessments, particularly assessments that encourage deep learning.

It would have been useful to also gauge the respective prevalence of learning-centred, learner-centred and teacher-centred approaches, but that level of detail was impractical to capture in the study presented here.

IV. Data collection and Analysis

A. Data sources

Since the study focusses on the enacted beliefs of those teaching engineering and was aimed at evaluating to what extent these actions were aligned with the espoused beliefs, the data sources were limited to the staff that are intimately involved with the teaching or the students that receive the teaching. It was somewhat surprising to find that the staff of centres that support development of teaching and learning usually had a poor overview of the teaching practices of their institution. This is probably because the staff members of these centres typically interact with teaching staff that are interested in innovative teaching styles or have particular problems that they need help with. The centres therefore interact with a small subsection of teaching staff and do not have an overview of the whole range of teaching styles.

To answer the research question with broad authority would require resources that were beyond the means available to the study reported here. Since it was impractical to elicit the views of the students within these limitations, this study used interviews with key stakeholders as research method. Selecting the stakeholders to interview presents particular challenges:

- There is a wide diversity of teaching practices within each institution (partly due to the diversity of contexts and partly due to the diversity of preferred teaching styles of academics).
- There is no central record keeping of teaching practices, with the possible exception where practices such as PBL are indicated in university course catalogues. Course outlines are a possible source of information on teaching practices, but their availability and level of detail on teaching aspects, are uncertain.
- The people that have the best oversight of teaching practices are, in my experience, the vice/associate deans, heads of departments and educational programme coordinators. However, they are universally extremely busy, thus limiting their availability as sources of information.
- A broad, but voluntary, survey of teaching staff (e.g. using an online survey) is unlikely to produce balanced information, since most staff members are also very busy and, if the survey is about teaching practices, it is likely that those staff members with a higher level of interest in scholarship of teaching and learning will answer the survey, while others will not. The survey's results will therefore not be broadly representative.
- Although teaching staff with a few years of experience usually have some knowledge of the teaching practices of their colleagues, and therefore can be a source of information beyond their own teaching, the accuracy of their perceptions will be limited. This is a particular concern where there is a stratification of teaching duties, as practiced at some institutions, where some

staff focus on teaching more junior level courses, while other staff focus on senior-level or graduate-level courses.

Eventually, the persons used as data sources for this study were determined by the availability of suitable persons on the dates I visited each institution. The persons interviewed are: KU Leuven: Prof Herman Bruyninckx (a staff member of the Department of Mechanical Engineering, Division for Production, Machine Design and Automation) and Prof Wim van Petegem (who was intimately involved in developing blended learning at KU Leuven and is an expert in multi-campus & engineering education, in the Faculty of Industrial Engineering Sciences); Pennsylvania State University (Penn State): Prof Christine B Masters (Assistant Dean for Academic Support and Global Programs in the College of Engineering); Rensselaer Polytechnic Institute (RPI): Professor Suvranu De (Department Head - Mechanical, Aerospace & Nuclear Engineering) and Professor Mark Steiner (Director of the O.T. Swanson Multidisciplinary Design Laboratory); Harvard: Prof Anas Chalah (Director of Teaching Laboratories, School of Engineering and Applied Sciences); Massachusetts Institute of Technology (MIT): Prof Rob Miller (professor in the Department of Electrical Engineering and Computer Sciences); University of Michigan (UMich): Prof Kira Barton (associate professor in the Department of Mechanical Engineering).

The institutions selected for the interviews were chosen on the basis that they are widely considered to be leading engineering faculties/schools with similar class sizes to Stellenbosch (up to about 250 students per lecture group), due a prior relationship that could be used to gain access to the required information, and due to logistical limitations imposed by my itinerary during a sabbatical. The predominance of institutions from the USA was by intent, since our four-year BEng programme structure is similar to the equivalents in the USA, in contrast to the three year bachelor plus two year masters used in Europe for engineering sciences focussed programmes. Also, the USA institutions offer engineering programmes that are ABET accredited (which is the Washington Accord equivalent of SA's ECSA accreditation), while the European universities are not yet part of the Washington Accord.

B. Data capture and analysis

As mentioned above, the data was collected by conducting interviews with key stakeholders (the persons are listed in the previous section). The three aspects of teaching practices mentioned in the Research Question section provided a broad structure for the interviews. I took handwritten notes during the interviews and later structured each interview's information according to the three aspects of teaching practices. After completing all the interviews, for each aspect, I compared the results from the different institutions with each other and with our practices at Stellenbosch University. The main results of these comparisons are given in the next section.

V. Observations and Deductions

In the Research Question section, the term "teaching practices" is taken to focus mainly on three aspects. The observations and deductions drawn from the collected data are described in this section, structured using the three aspects.

A. The aspects of curriculum structure that have strong effects on pedagogy

1) Bachelor's and master's structure

As mentioned above, the USA uses a four-year engineering programme structure, similar to our BEng, while KU Leuven's Faculty of Engineering Sciences uses a three year bachelor plus two year masters, as mandated by the Bologna Accord. However, the differences in the programme structures do not lead to significant pedagogical differences in the first three years. The first year of the masters in KU Leuven has a pedagogical character that is a mix of the fourth year of undergraduate engineering programmes and taught masters of the USA and SA. In the undergraduate programmes, students' learning is more formally directed by the lectures, while in the taught masters (in the USA and SA) students are expected to work more independently. Some of the master's courses at KU Leuven were more formally directed, while others expected more independent work of the students.

2) Common core/first semesters

The advantages and disadvantages of a common first year for all engineering disciplines in a faculty is a matter of perennial debate in my faculty. Advantages include practical aspects (such as the cost effectiveness of larger class groups and allowing better support measures aimed at helping first year students with the transition from school to university) and notional aspects (such as that all engineers should have a common mathematical and scientific base), while disadvantages include the loss of motivation by the students (due to lack of contact with the engineering discipline they enrolled for) and compromises made in the curriculum (where, for a given discipline, "less important" general content is included in the common year at the expense of "more important" discipline-specific content, or content is placed "too early" in the curriculum for the sake of commonality, while students would be better able to master the work later in the curriculum). It was therefore interesting to determine what leading institutions do in this regard: The spectrum ranges from having the first three or four semesters common for all disciplines (at Penn State and KU Leuven respectively), through having a common first year for the whole institution (at MIT) or all engineering disciplines (at UMich), to having a common core of mathematics and sciences spread over the first two years (at RPI). It is therefore a clear indication that leading institutions prefer strong commonality in the first part of the engineering programmes.

3) Project based learning

As mentioned in the Research Question section, much has been written about the value of increased PBL, but that for large class groups, the practical implications of offering PBL can be significant barriers. In this respect, the data collected showed widely varying practices, not only between institutions, but also between programmes in the same institution.

On the one extreme one can place Harvard where 25 to 40% of courses (depending on the discipline) use PBL. Up to 45% of their courses have a strong design element and the senior (fourth) year has one semester of only project-related work. More junior courses have less project emphasis. However, Harvard's capstone projects are typically done individually, not in teams.

KU Leuven also has a strong faculty-wide PBL focus in that it each of their bachelor's programmes first three years has one PBL course. The students are guided during these projects by PhD students. Beforehand, the PhD students do a credit-bearing course where they are equipped to guide such groups, using a framework of guidance roles [7]. However, at KU Leuven the bachelor's programmes do not contain an individual capstone project (while, apparently, at some other European universities the bachelor's does), but the master's programme does contain a major individual project.

On the other extreme one can place Penn State that has no PBL in the first two (common) years. In further years PBL courses differ from programme to programme. Some, like mechanical engineering, have a formal PBL course in the third year, while others have projects embedded in other courses. All programmes have capstone design courses which are mostly done in teams. Some programmes make use of a "Learning factory" for their capstone design projects. One programme uses individual research projects as capstone project.

RPI has a very successful approach of using industry-sponsored capstone projects. Eight students typically work together on these projects. Engineers on the staff of the department, funded from the industry sponsorships for the projects, provide technical supervision to the teams, while academic staff members provide academic supervision. Assessment of the individual contributions of team members is done by peer-evaluation and by faculty members.

B. The spectrum of pedagogical approaches used

One significant pedagogical approach, PBL, is considered in the previous section because it is more closely associated with the curriculum structure. This section considers further approaches.

1) Blended learning

Much has been written about the use of information technology or learning technologies in university education. In this section I broadly group related pedagogical approaches under the banner of "blended learning". In spite of what has been reported about blended learning's importance and relevance to today's students, a closer inspection finds little evidence in the literature of widespread use at present, and also little published research that shows that blended learning approaches are effective alternatives (in terms of the resources required from the institution and the student) to more classical teaching.

A significant observation was that in all the institutions visited, the use of blended learning is the prerogative of the lecturing staff member responsible for a course, although institutional "encouragements" of various forms may be offered.

Of the institutions considered, KU Leuven and RPI appeared to have the most significant penetration of blended learning, but even in these institutions, the use of the flipped classroom approach, one of the more radical forms of blended learning, is rare in engineering programmes (probably fewer than 5% of courses are flipped). At all institutions visited, the use of flipped classrooms is limited to one or two lecturers in specific courses. At RPI only a few undergraduate courses use flipped classroom, since it is more work for the student, while flipping was more common in graduate courses. On the other hand, MIT reported that flipping occurred more frequently at junior levels than at senior levels.

Video recording of lectures on a regular basis is as rare as, or even rarer than, flipped classrooms since few of the persons interviewed were aware of this occurring in their faculties, except that Harvard and UMich reported that some lectures are recorded. The infrastructure required to make recordings of lectures is not readily available at all institutions. KU Leuven is best equipped with approximately three small, three medium, and three large venues (shared by the SET, humanities and medical faculties) equipped for lecture recording, as well as some mobile units. Lecturers have to book these venues on an ad hoc basis, while if a lecturer would want to systematically record all the lectures of a course, it would have to be arranged well in advance. KU Leuven has an in-house developed platform to disseminate videos. The preference for in-house development of the platform has diminished with commercial platforms becoming available and the increased burden of updating the platform for the increasing variation in users' devices.

The use of videos made off-line was encountered at all institutions, although the depth of penetration of this approach was difficult to quantify. What was clear is that off-line videos were much more common than video-recordings of complete lectures.

Wi-Fi is widely available on the campuses and in the lecture venues of the institutions surveyed, but the bandwidth is too limited in most cases to handle intensive uses such as live video streaming to all the students in a class. Typical uses included response software (e.g. those that emulate clickers and Twitter) and access to learning management systems (e.g. Blackboard or Moodle).

All the institutions had a type of clicker platform that lecturers could use. KU Leuven has a license for "Poll Everywhere", a web-based classroom-interaction tool, while the USA institutions had a physical clicker brand that their institution standardised on. Students were expected to buy their own clicker if they enrolled for a course that used clickers. At RPI, about 20% of classes regularly use clickers and about half of the lecture venues are equipped for clicker use. Each "freshman" receives a "technology bundle", which includes a clicker, a laptop and software. An interesting comment received at RPI is that, although the currently used clicker technology is very reliable, it is still subject to the response units' batteries going flat or students forgetting the clickers at home. My impression is that at other institutions, clickers (or software equivalents) are used in less than 10% of courses, possibly because of the preparation required of the teaching staff to properly integrate clickers into their pedagogy.

2) Type of contact sessions

As indicated above, the use of PBL and flipped classroom approaches are limited to a minority of courses in engineering programmes at the institutions included in the survey. This section therefore considers the use of the other, more traditional, contact sessions where teaching staff and students interact. Two modes of contact sessions are distinguished here: the first mode is lecture sessions where a lecturer presents material (e.g. theory, examples, demonstrations, etc.) to students, with some limited participation from the students (e.g. asking questions, answering short questions posed by the lecturer with or without a clicker system, etc.); the second mode is here

called tutorial sessions where students work under the supervision of the teaching staff (lecturers and/or teaching assistants) on problems assigned to them, where the problems are typical of what can be expected in the main assessments of the course. I acknowledge that not all contact sessions fall into either one or the other category and that the two modes can be combined in a range of proportions in one contact session, but in my experience, the two modes still do offer a useful distinction.

The amount of time spent per week on lectures and tutorials, as well as the division of the available contact time between the two modes is of interest since the contact sessions require substantial resources to offer and, probably second to the assessments, have one of the strongest influences on students' learning.

At KU Leuven, in the bachelor's programmes, typical courses use a format of one lecture slot of two hours per week and two hours per week of tutorials, with 13 weeks of teaching in a semester. Teaching assistants supervise and prepare tutorials. At all the institutions surveyed in the USA, the equivalent courses have three to four hours of contact per week. The split between lecturing and tutorials vary from course to course, as determined by the lecturer. At Penn State, one third lecturing and two thirds tutorials is the most common approach, while at UMich, more than half of the contact time is typically spent on lecturing. The semester at USA institutions typically has 15 weeks of contact. The lectures are commonly presented to large class groups (a size of 200 is not uncommon), while at some institutions, the class is split into smaller groups for tutorials (Penn State aims for about 30 students per teaching assistant).

C. The formative and summative assessment practices

On the one hand, assessments are well known to have a strong influence on students' learning (formative assessments are, in particular, important in this context). On the other hand, substantial resources are required to create and mark assessments, particularly regular formative assessments that encourage deep learning. Also, one of the exit level outcomes required for accreditation of an engineering programme in South Africa is that the students must demonstrate the ability to learn independently [10]. Washington Accord compliant programmes, such as ABET-accredited engineering programmes in the USA, will have an equivalent requirement. Finding a sound balance between helping students learn through feedback on formative assessments, while also expecting students to learn independently, is therefore important for engineering programmes. This section considers how the institutions included in the survey address this balance.

PBL is a particular form of teaching and assessment where the two aspects run concurrently. PBL is therefore different from most other assessments. However, as pointed out above, PBL is used in a relatively small fraction of courses in the engineering programmes considered here.

Non-PBL courses encountered in this study predominantly have regular formative assessments during the semester, often as part of the weekly tutorials or homework assignments. Normally these formative assessments make a small contribution to the students' final marks, since many students tend to neglect formative assessments if they do not contribute to the final mark. A noteworthy observation is that all the institutions included in this survey routinely use weekly formative assessments in all the years of their undergraduate programmes (except PBL courses). This applies also to KU Leuven's bachelor's programme, as well as to some courses in their master's programme. This is contrary to the perception amongst my colleagues that European engineering programmes use few assessments during the semester.

All the institutions surveyed used a semester system with a small number of major assessments to determine the largest part of students' final marks in non-PBL courses. KU Leuven is unusual in that it normally has no major assessments of this type during the semester. This university only has an examination at the end of each semester and a supplementary examination before start of the academic year in September. KU Leuven's academic exclusion policy is also clear and straight-forward: a student can have at most four examination opportunities to pass a course (two in each of the corresponding semesters of consecutive years of study) and if the student has not passed a course in these opportunities, the student is excluded for five years. If the student has not passed the course at first attempt, the student can choose whether to attend the contact sessions during a second attempt. In the engineering bachelor's programmes at KU Leuven, most examinations are in written form, while in master's programmes most examinations are at least partially oral. Oral examinations can be conducted by the relevant professor alone, but sometimes the course's teaching assistant is present.

At Penn State, homework and formative assessments vary widely, from only one or two midterm tests to weekly homework that is marked (either just for attempting or for correctness too). Most courses have at least two mid-term tests, which act as formative and summative assessments. After the end of classes, there is one examination, which usually covers all of the semester's work. There are no regularly scheduled supplementary exams. If a student is sick during a major assessment, the instructor typically makes an ad hoc arrangement with the student. If a student fails the course after doing the examination, the student must repeat the course. RPI, MIT and UMich use a similar approach, except that usually students are required to submit weekly homework. This homework sometimes (often at RPI, but rarely at UMich) uses the online facilities of the publishers and is graded automatically. At RPI the examination typically contributes up to 30% of the final mark.

Another notable observation is that none of the institutions included in the survey has formal systems of internal or external moderation. This is in contrast to the extensive internal moderation of courses, as well as external moderation of all exit level outcome assessments, that is expected by the South African accreditation body.

VI. CONCLUSION

This study shows that some aspects of teaching practices in engineering education at leading institutions have changed in recent years, with the increased use of PBL and the limited introduction of elements of blended learning the most noticeable trends. However, these modes of teaching are still used to a limited extent and PBL is usually not applied to analysis-type courses. The classical teaching format of lectures (where communication is mostly from the lecturer to the students) plus tutorials (where typical "end of chapter" problems are assigned to students) is the dominant teaching

practice at all engineering faculties included in the study. However, a wide range of teaching practices are still used and the instructor's preference is a dominant factor influencing the practice employed in a specific course.

Formative assessments, in forms similar to weekly homework assignments that are marked by teaching assistants, are widely used in all institutions at undergraduate level. In a majority of undergraduate courses, the largest part of students' final marks is determined by one assessment at the end of the semester and, in many cases, one of two major assessments during the semester.

Four of the six institutions included in the study start their engineering programmes with two to four semesters common between all mainstream engineering programmes. One institution has a common core, but already differentiates somewhat between programmes in the first year. This study, therefore, shows that a common start to engineering programmes is more of a rule than an exception.

When considering the general validity of the above observations and deductions, it is important to note that they are based on very limited data sources. The scarcity of data sources prevents that triangulation be used to minimise the effects of subjectivity and the partial experience of the persons interviewed. However, the commonality found between the different institutions included in the survey does give some measure of triangulation, which strengthens the validity of the results.

In my view, the overall finding of this study is that many aspects of teaching practices in engineering education at leading institutions have changed much less than what one may expect from the reports in the general and educational media. I suspect that lack of widespread innovation in teaching approaches in engineering is partly due to the following considerations:

- Engineering curricula are highly loaded. Some of the teaching innovations actually increase the time that students need to spend on their academic work, while time is already at a premium.
- Engineering students often study in "burst mode" [9], while many innovative teaching methods rely on students working steadily on each course.
- The general perception that current teaching practices are producing good (or good enough) results, strengthens the perception that the risks involved in teaching innovations are not worth the small rewards and large effort that accompanies innovation.

Assessing the impact of the above considerations would be a worth-while study.

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Teaching Engineering in sub-Saharan Africa: The need for 'Pracademics'

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***Abstract* - This paper aims to lay the ground for engineering education institutions in sub-Saharan Africa to more actively seek to employ pracademics. There are many challenges to tertiary engineering education. Many are beyond the control of individual dons. However, those about curriculum and effective teaching, could – to some extent - be addressed. Two types of academics are looked at: the traditional 'pure', and the practicing professional - a 'pracademic'. The 'pure' academic's job is re-modelled to more clearly address current industry needs without compromising its integrity. This creates seven job elements, four of which occupy the traditional 'Teaching' portfolio. The differences between the 'pure' academic and the 'pracademic' is modelled mathematically and explained physically so that those who want to convert are availed the mechanics of doing so. Likewise - for those from industry. The paper then focuses on 'Teaching' to illustrate how both lecturer and students can address industry's or society's needs. This is done systematically in the 4 job elements. The pedagogy used is Project Based Learning. Examples of assigned projects and results therefrom are given. It is seen that a pracademic has a continuous stream of real life projects from outside that can be used in each of the 4 elements. Hence, s/he is better equipped to do the remodelled job. Other benefits are cited, and so are challenges. On balance, the benefits far outweigh the challenges and therefore it is strongly recommended that the region's engineering institutions adopt the model and seek pracademics in their employ.**

***Index Terms* - Engineering education, Pracademic, Project based Learning, sub-Saharan Africa, Research, Service**

1 INTRODUCTION

It is well known that socio-economic development and transformation of a country largely depend on the means of production and level of technology deployment in that country [1], [2]. Whereas people in developed countries take use of machinery in their supply chains for granted, it is common to find educated people uncomfortable with use of machinery and Technology in sub-Sahara Africa. Ref. [3] for example cites Technophobia as one of the challenges of e-learning in Nigerian secondary schools. The application of the natural sciences to engineering design to solve Africa's problems is largely undertaken with help of foreign engineering professionals. The effects of this reliance are numerous: Not least is the cost of engineering projects and the time lag between project conceptualisation and delivery [4]. But more importantly, there is the effect on building self-confidence among local engineers and engineers to be. As an example, a significant fraction (>70%) of own engineering students from 2006 to date at two universities in Southern Africa sub region, thought 'Engineering' was principally a 'Western' and largely 'male' profession. That is - until challenged about the rise of China and India. Earlier in industry, at a 1989 management conference of one agricultural multinational company in East Africa, a suggestion to research and develop local organic based fertilisers for the company's major crop was rejected by the Manager in charge of the Agricultural department on claimed grounds that: "*all research has been – and still will be - done in Europe*" [5].

This paper asserts that the engineering academic in these circumstances is required not only to build the knowledge base of students but also is challenged to transform their basic thought processes while also providing enlightened leadership to build confidence among practitioners. Elsewhere – especially in developed countries – the latter demand on engineering dons is less of an issue because of a higher engineer to population ratio and of the bigger numbers of support artisans and technicians in the profession. In India, China, US and Europe with current annual outputs of graduates similar to those in Table I, there can hardly be an issue on lack of engineers to tackle problems similar to those faced by Africa ([7], [8], [9]). The issue may be how to spot the very good ones from among the millions available – but certainly not that there will be a lack of choice – as is the case in most of Africa.

Table I. Numbers of graduating Engineers in 2015 for some countries

Country/Region	Thousands	Reference
India	1500	[6]
China	1300	[7]
Russia	454.4	[8]
USA	237.8	[8]
Iran	233.7	[8]
France	104.7	[8]
South Africa (2011)	9.4	[9]

The challenges to sub-Saharan Africa's engineering education are all too documented and too well known to warrant another detailed listing here. However, for purposes of laying the groundwork for section 3, the main stay of the paper, Table II is provided for quick reference to extended discussions of the problems.

Table II. A summary of key issues in sub-Sahara Africa's Engineering Education

Area	Issue	Some References
Governments	Policy on Engineering Education	[10]
	Data on required supply or expected demand	[10]
	Funding	[12], [13], [16], [18]
Universities	Curriculum	[10], [11], [12], [14], [18]
	Product design syllabi	[10]
	Management & Entrepreneurship for Engineers syllabi	[10]
	Textbooks	[12], [14]
	Labs and workshop facilities	[10], [12], [13], [16]
	Student numbers	[12], [13], [16], [18]
	Quality of students entering Engineering faculties	[15]
	Women entering Engineering faculties	[10]
	Trained staff	[12], [13], [14], [18]
	Teaching Methods	[11], [12], [13], [18]
	Industrial disputes	[18]
Industry/ Society	Over expectations from universities	[17]
	Industry-university cooperation	[12], [13], [16], [18]

In this paper, an attempt is made to show how some of these challenges could be better addressed through use of an engineering pracademic. First, in section 2, the pracademic is introduced and described. The principal job elements that implement necessary student curriculum are outlined. This is at the abstract level. In section 3, the abstraction is translated to practice by demonstrating a series of real world problems which the students were enabled to address. The technical and educational results of this work are presented along with respective cases. Section 4 presents a summary of opportunities and challenges an engineering pracademic might expect especially in sub-Saharan Africa. Finally, conclusions are drawn and a recommendation is made.

2 THE PRACADEMIC

A Pracademic is someone who is simultaneously an academic at a university and a practitioner in her/his primary profession [19], [20]. As an academic, 3 responsibilities are expected of her/him: Teaching (T), Research (R) and Service (S) (e.g. see [21]). The first two are more confined to the university environment but the third can – and often does - extend to the outside society. As a practicing professional, the responsibilities are more oriented to society outside the university. Therefore, the 'S' role in the pracademic's job plays a bigger role than in the ordinary academic's. This marks the major difference in practical roles. Fig. 1 shows a simplified illustration of relative importance of the various job elements for a pure academic and a pracademic.

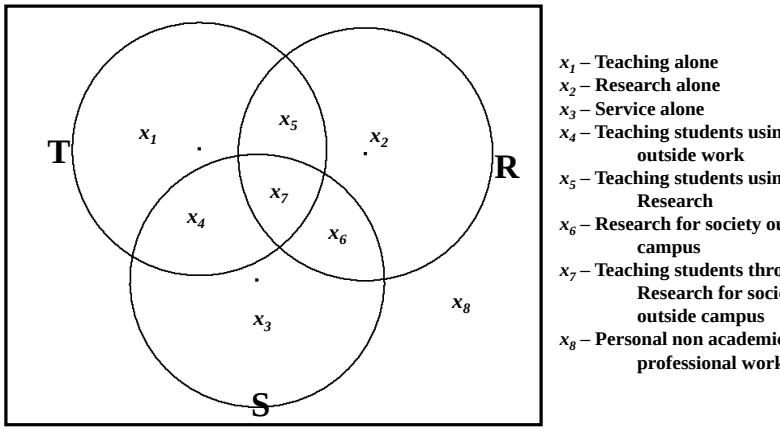

Fig. 1. The relative proportions of importance of different job elements in 'T', 'R' & 'S"

In the figure if x_i be the relative importance of job element *i*, then:

$$\sum_{i=1}^{8} x_i = 1 \qquad (1)$$

For the pure academic,

$$n(T \cup R) = x_1 + x_2 + x_4 + x_5 + x_6 + x_7 = 1 - (x_3 + x_8) >> n(S) \qquad (2)$$

This leads to:

$$x_1 + x_2 >> x_3 \qquad (3)$$

For the pracademic,

$$n(T \cup R) \approx n(S) \qquad (4)$$

So that

$$x_1 + x_2 \approx x_3 \qquad (5)$$

Equations (3) and (5) explicitly give the difference between the two types of academics. The importance attached to pure teaching and pure research by the traditional academic is much more than that to solving problems outside campus. For the pracademic, outside problems are about as equally important as in-campus activities.

The mechanics of being a pracademic depends on what drives that choice. Walker [20] gives two possibilities. Either someone is initially in industry – and s/he develops a desire to enquire more thoroughly on the experiences s/he encounters; or s/he is initially a pure academic but picks deep

interest in applications of what 'Theory' seems to suggest. The former is 'Practical' based but 'Theory' driven while the latter is the reverse. The 'Theory' driven pracademic may begin by seeking a part time appointment with the university. In equation (5), s/he starts with a very strong value of x_3 (i.e. at $x_3 >> x_1+x_2$) and then grows x_1 and x_2 without necessarily having to compromise the overall effectiveness in '***S***'. This is achievable by growing fractions x_4, x_6 and x_7 at the expense of x_3 (and where there is element of 'overwork' at partial expense of x_8). The options available to a 'Practical' driven pracademic in transiting from equation (3) to (5) are many. But basically x_1 and/or x_2 (and x_8 for 'overworked' people) are diminished through a reallocation to any or a combination of the other fractions. For engineering pracademics, the different pathways to becoming one yield different opportunities and challenges – as will be shown in section 4.

In Fig. 1, lecturer interaction with students to nurture their knowledge, skill and attitudes bases occurs in the teaching role '**T**'. The pracademic's job elements in that role are assigned proportions x_1, x_4, x_5 and x_7. The work described below gives examples of work done in respective elements – and shows how some of the challenges mentioned in section 1 were addressed using the pracademic's industrial exposure.

3 TEACHING USING INDUSTRY/SOCIETY PROBLEMS

This report presents four case studies corresponding to the 4 job elements in '**T**' of Figure 1. In each element, a typical activity is described and consequent results are discussed.

3.1 Case No.1 (x_1): Teaching Process steam plant equipment in *Thermodynamics*

Many *Engineering Thermodynamics* syllabi at undergraduate level do not seem to include auxiliary equipment for process steam. The '*Steam Plant*' syllabi tend to emphasise the power plant, and even then, it is major equipment i.e. Boilers, Turbines, Condensers and Pumps which are discussed. Moreover, standard western text books on the subject only refer to these items (e.g. [22], [23]). Yet, perhaps up to 90% of steam use in industry is for process purposes. And in these, the smaller items like steam traps, separators, de-aerators, and even pipelines with their insulation can be a major source of trouble.

In 2011, consultation opportunities for 2 Cape Town process steam plants arose. As the work was of confidential nature, the students were not directly involved. However, the culprit devices (steam traps in this case) were discussed in class and the thermodynamics of their operation was thoroughly explained. Onsite experimental results of tests (done only by lecturer) were used to illustrate what can go wrong with these items. Later, in a summative assessment, the students were tested on their understanding of these devices. Results showed that the question on these items was better answered than any of the others – see Fig. 2.

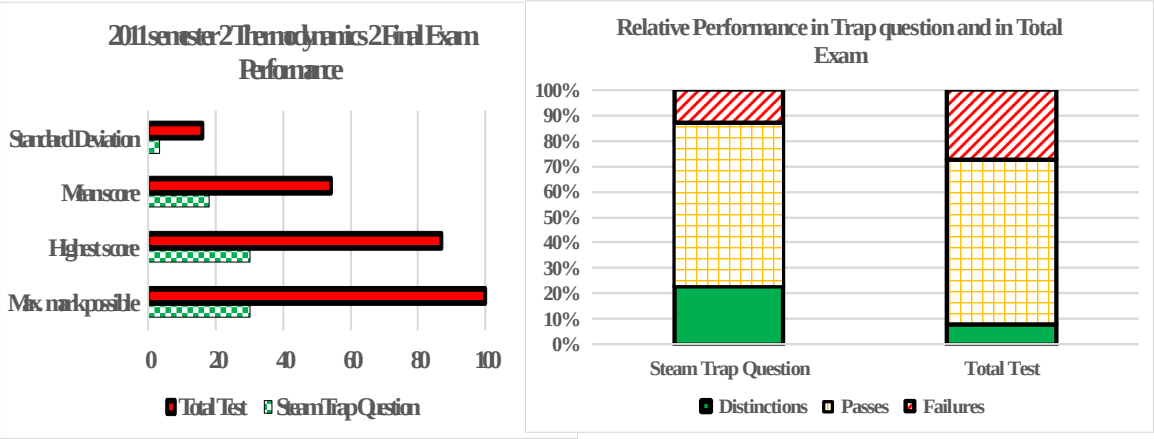

Fig. 2. 2011 Semester 2 Class performance in Trap question – compared to total exam performance. No. of students = 92

3.2 Case No.2 (x_4): Teaching students to design for society

This case describes work of another pracademic at the university. It shows an activity in which the lecturer guided students to address a local community problem of water heating.

In 2011, a group of Bachelor of Technology students was assigned a project to design, construct, install and commission a low cost solar water heater for communities in settlements around Cape Town. This was a cooperative project with The Hague University of Technology (HUoT) in Netherlands. The students were first sensitized about warm water needs of people living in informal settlements around Cape Town. They were then accorded an opportunity to go to the Netherlands to interact with colleagues at HUoT for two weeks. While there, an engineering solution was agreed on, and a prototype constructed. They returned to South Africa with some of HUoT colleagues. Tests were done at campus and a presentation made to Mechanical Engineering staff of CPUT. The prototype was then installed at one of the neighbouring community centres. Its performance has since been monitored for improvement in future designs. Fig. 3 shows the system installed at the community centre.

Fig. 3: The Solar water heater installed at a community centre (courtesy of CPUT: Mech. Eng. Dept.)

3.2.1 Immediate performance results

Fig. 4 shows the results obtained from prototype tests. It shows that the students' system successfully generated warm water within one hour of a sunny summer day, and therefore the students properly responded to society's need for low cost warm water.

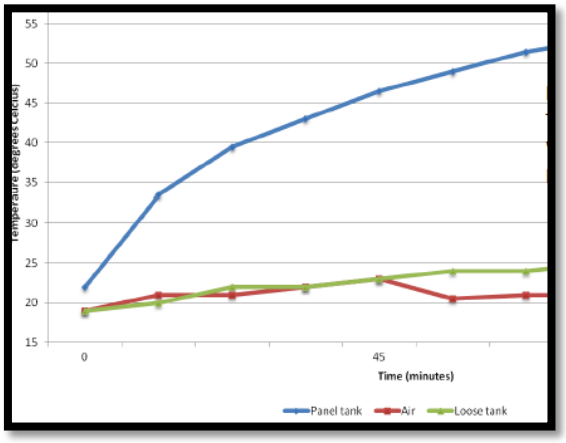

Fig. 4. Tank temperature variation on a clear summer day (courtesy of CPUT: Mech. Eng. Dept.)

3.3 Case No.3 (x_5): Teaching use of solar energy through Research by students in *Thermodynamics*

Again, many undergraduate curricula do not include a study on renewable energy as a main stream subject. Also, most western *Thermodynamics* and *Electrical Engineering* books do not treat this topic with the attention that Africa would require. Yet, the continent's energy problems are well known, and the need for distributed home level solar energy harnessing or even community level photo voltaic generation is well expounded (e.g. [24], [25]).

In 2012, the particular pracademic was beginning his research on solar energy harnessing systems for domestic home applications. He therefore assigned final year *Applied Thermodynamics* students the following research assignment: *In this assignment, you will work in a team of unfamiliar people to gather data on solar energy harvest with in South Africa and/or elsewhere on the African continent. The idea is to prepare you for a possible future scientific or entrepreneurial assignment in solar energy harvesting within the country or anywhere else on the continent. Because of the scale of the project, your group has been assigned a specific task -------.*

For a group assigned to gather data in one of the suburbs of Cape Town, the detailed instructions included: *"--- Check how the solar collectors are commonly specified; determine their dimensions and other physical parameters (e.g. mass, moments of inertia etc.) and how they are installed. Check their orientations to the sun and report accordingly ---"*

In this assignment, the students made two reports: an individual one on learnings from the exercise; and a team one showing their findings. These, together with a team presentation constituted one of the assessments in the semester. The results of the activity were interpreted qualitatively and quantitatively.

3.3.1 Qualitative analysis

The individual one page reports were analysed for comments on positive and negative learning experiences. It was found that almost all students who turned in individual reports, rated the activity very highly. The main benefits reported included: forming new friends across cultural and nationality lines; Learning to listen to others in a team; Sharing and seeking help on personal problems from colleagues. In terms of new learnings, many reported increased awareness of Africa's geography. One student even wrote thus:

"I do not know why Geography is not compulsory at Matric. It is such a lovely thing to know about other places"

Yet another wrote:

"Now I know Engineering is about working with people: not just calculations"

There were few negative experiences. Time constraints, lazy teammates, having to go around Cape Town at own cost in search of solar equipment, and some uncooperative/suspicious industry practitioners - were some of the reported negatives.

Overall, these results were heavily biased towards a transformative change. Students were querying their long held views and experiences. They were exploring new areas of knowledge, not normally encountered in engineering classrooms.

3.3.2 Quantitative analysis

The scores from the exercise were compared with those from non-project activities such as summative assessments and lab reports. The results are shown in Fig. 5. They clearly show that the project was much better performed – and that it significantly improved the final class averages. The standard deviation to mean ratios show that general understanding of the work in the activity was more uniform than among other assessments. To that extent, the activity was beneficial to students (by improving their total evaluation mark) and to the pracademic (by assuring that his efforts had been more uniformly rewarded).

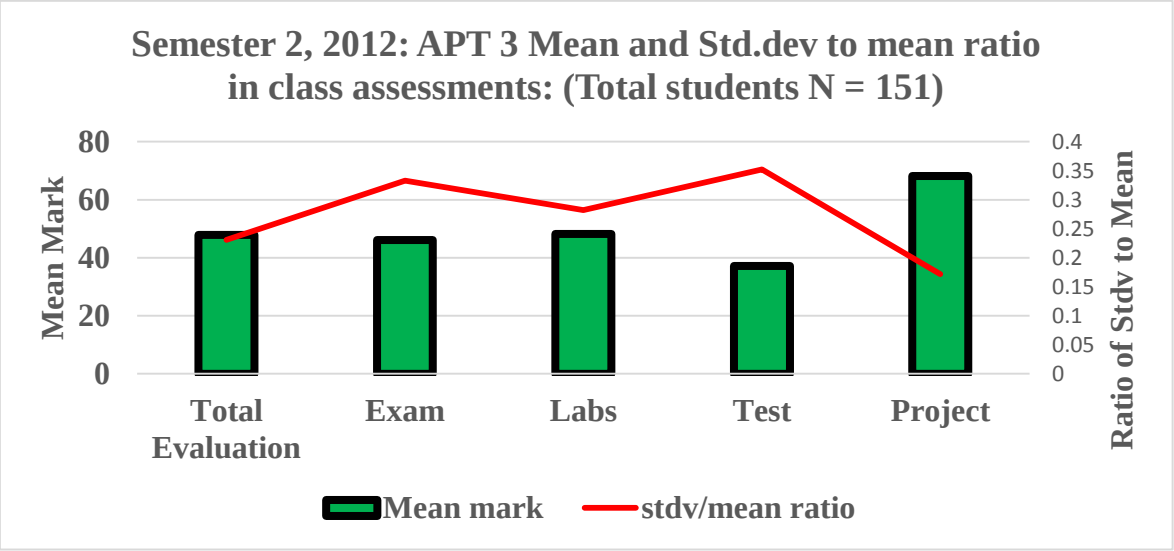

Fig. 5. Comparative performance means and standard deviations in various assessments

3.4 Case No.4 (x_7): Teaching use of solar energy to solve society's problems through Research

This case illustrates an attempt to contribute to addressing rural Africa's post-harvest fruit and vegetable losses by involving students in the pracademic's research work on solar energy systems.

Fruits and Vegetables are better preserved by refrigeration because this process has the least effects on their freshness and nutritional value [26]. There are different types of refrigeration systems, the commonest being a vapour compression type. This requires a source of electricity, most commonly the alternating current type – which is best obtained from a grid supply line. As an offshoot of the pracademic's work on photo-electrifying SSA energy-poor homes, a Masters student was tasked to design and test a photo-voltaic - run refrigeration system to meet a daily harvest of about 20 kg of fruit and/or vegetables for a small scale farmer. This was successfully done in 2016 – as shown in Figure 6.

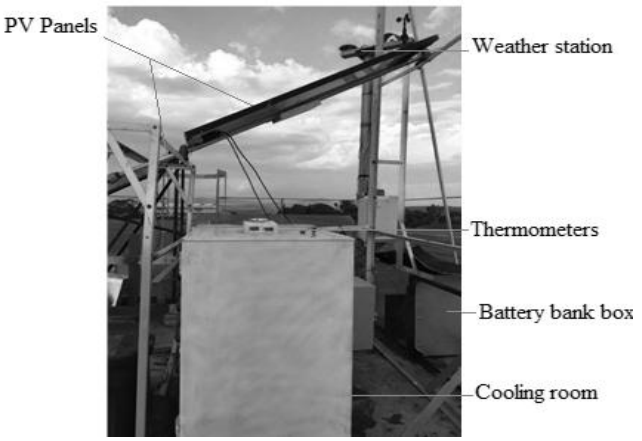

Fig. 6. The outdoor PV 12 V DC refrigeration system and its two cooling curves for 20 kg of straw berries [--].

4 OPPORTUNITIES AND CHALLENGES

In this section, opportunities and challenges of 'pracademia' as noted by some researchers are summarised. Own observations are interjected where necessary.

4.1 Opportunities

There are benefits to students, lecturers and industry or society if an engineering faculty has some pracademics on its staff list.

4.1.1 Benefits to students

Ball [27] gives ability to link Theory to Practice and exposure to rigours of real working life in form of tight deadlines and budgets as important experiences availed to students by pracademics. Wilson *et al.* [28] adds development of leadership, managerial and entrepreneurship skills. In addition, the following are evident from cases of section 3:

- The student learns more of what is relevant in industry than what a syllabus or a prescribed text book may contain.
- The student learns more of the interconnectivity of knowledge areas, including those s/he would never have met in a normal engineering curriculum delivered by a pure academic.

4.1.2 Benefits to Pracademics

Susskind [19] lists many benefits of being a pracademic from his own perspective. But it is important to understand that he is the type that moved from industry to academia. These benefits include:

- Job satisfaction independence of traditional university processes and cultures
- Ability to teach in many different contexts
- Deriving satisfaction from what has 'actually worked' and not necessarily from what has been 'published' especially as reviewers may have different standpoints

To his longer list, could be added the following:

- Teaching with authority and confidence, thus making the delivery not only more believable but authentic.

- Ease in preparing assessments that relate to what industry requires than straightforward text book type questions.
- A virtually unlimited source of realistic class and research projects
- Unrivalled academic satisfaction from a complete understanding of the theory behind a working device, especially if that device is an invention, or one designed *de-novo*.

4.1.3 Benefits to Industry/Society

Perhaps, the greatest beneficiaries from using pracademics in engineering faculties are industry and society in general. Better taught and trained graduates are produced by such faculties, possibly reducing induction time and costs incurred by employers after recruitment. A bigger number of pracademics would most likely increase the probability of some students turning out as entrepreneurs in their own right, thus creating employment in the economies.

4.2 Challenges

There are many problems about 'pracademia'. Murphy [29] and Susskind point to the universities' traditions of directing rewards to specialist knowledge creators other than to the prized 'all-rounders', preferred by industry. Universities prize publications while industry prefers patents. The pracademic from industry is thus by nature, 'less welcome' than that from academia.

Differences in work culture matter. Industry works on strict schedules, targets on quantity, quality, cost and customer care. And if private, it is generally lean on staffing. Not quite for universities. To a performance driven practitioner, there is relative laxity in universities. This can be frustrating. Moreover, key decision making and authority tends to be vested either in '*paracademic*' or in non-academic staff far removed from the mission-critical functions of the university.

To students, the rigour and hard work demanded by pracademics relative to that from pure academics (and sometimes to that advised by *paracademics*), can be distressing. The fuzzy nature of industrial problems is at first frightening.

5 CONCLUSION

This paper has laid ground for engineering faculties in sub-Sahara Africa to argue a case for attracting and retaining pracademics to their staffing. The problems faced by the institutions/faculties in the region were highlighted. Many were beyond the control of the engineering academic. But that is not to say there cannot be a try. It was suggested that as a way forward, problems of inappropriate curriculum could be addressed by examining what is required in the region's industries and societies, and then curricula re-tailored to meet those needs. Implementing of such curricula would ideally require active involvement of practicing professionals, able to cope with rapid developments in industry, changing needs of society and having the academic preparation necessary for university teaching responsibilities. This was the pracademic. Seven job elements covering the 3 roles of a 'traditional' lecturer of teaching, research and service were identified. The difference between the two was modelled and explained.

Two routes to becoming a pracademic were given. Then, examples of the 4 elements in the teaching role were described, and their results given. From those results, and from a bit of literature on the subject, benefits of the approach were identified. They included student acquisition of essential engineering knowledge, not normally in their syllabi or texts, introduction to real work situations, connecting theory to practice, etc. Benefits to the lecturer and to society were numerous. Challenges were listed – but most of them revolved around the difference in work cultures of industry and universities. If good numbers of pracademics are to be attracted, especially from industry, universities will need to relook at their relatively lax work environments. All said, the pros for use of pracademics seem to far outweigh the cons. Hence, it is strongly recommended that sub-Saharan Africa engineering institutions make concerted efforts to obtain them whether from within or from industry.

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Competence-Driven Engineering Education: A Case for T-Shaped Engineers

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Abstract **- The demand for engineering education and graduates are increasing daily because the current service and technological designs are unable to meet the needs of the society and the expected dramatic increase in the future The emerging skill gap requires a shift in the type of expertise required of young professionals that will be needed to successfully lead organizations in the new economy. Researchers have identified various 'shapes' for the engineering professionals to make them relevant to the 21st century challenge especially in the industry where their expertise is much needed. The purpose of this paper is to present the need to upgrade engineering education curriculum to enable a more T-Shaped graduate engineers required in the changing industrial world. T-shaped professionals have problem-solving and complex-communication skills in contrast with the traditional and highly specialized I-shaped professionals among others. The potential benefits of T-shaped professionals to organizational performance are quite significant and hence the demand for T-shaped professionals in knowledge-intensive, service-oriented economies is increasing. Unfortunately, the challenges associated with creating more T-shaped professionals are also significant. National regulatory bodies for engineering education in Nigeria are beginning to move towards integrated curriculum to break down discipline silos and produce T-shaped graduate engineers for the fast-changing industrial world. Service Science Management and Engineering (SSME) is an emerging discipline with over 250 programmes in 50 nations seeking to create more T-shaped professionals.**

Keywords **- education, engineering, graduates, skills T-shaped**

I. INTRODUCTION

In a fast-changing environment, organizations face conditions of growing complexity that challenge decision-making and innovation activities, highlighting an increasing need to develop dynamic capabilities [1]. In fact, there are two roads a new designer can travel. One leads toward a career as a specialist, one toward a career as a generalist. Why not a two-track system of design education? [2].

Company managers are generally satisfied with the technical skills of their new workers. What they truly need, however, are graduates with strong technical skills who also are adept at written and verbal communication, who understand how to get things done in a complex, fast-moving organization, and who can be depended upon to interact positively with co-workers, partners, and customers. These traits used to be called "soft" skills, but technology companies seeking a competitive edge increasingly seek employees who embody them [3].

The Dash - shaped skilled people have some knowledge about everything, a generalist and usually also provides low value added. The I-shaped skilled people need to be good at something that not many people on the market are good at, and there is even more value added. A combination of Dash-shaped and I-shaped skills in the team gives a really powerful combination. When it comes to complex problems in the business world that are more difficult to solve, interdisciplinary teams provide the most value since teams are becoming more important than individuals [4]**.**

The term "T-shaped" isn't new: it's been in use since the 1990s but mostly in consulting and technical fields. The idea of T-shaped skills was first mentioned by David Guest in a 1991 article discussing the future of computer jobs but it is now more important than ever. The world is becoming more and more complex and T-shaped skills are a razor that can cut through all the complexity [5].

The concept of T-shaped skills described the attributes of desirable workers. A T-shaped person is someone with T-shaped skills. The concept of the T-shaped professional refers to individuals with both depth and breadth of knowledge as shown in Figure 1. The vertical bar of the T reflects a deep expertise in a single area, usually technical, while the top or horizontal bar of the T refers to an ability to collaborate with

experts in other disciplines and a willingness to apply or use the knowledge gained in areas of expertise other than one's own [5].

Leading enterprises look for engineers that are able to deal with changing customer needs, greater competition, and shifting markets. Companies now expect graduates to be work-ready right at the start. Employers expect new workers both to hit the ground running and to maintain relevant new skills through lifelong learning, self-directed and on their own time. Of course, industry has been known to be more dynamic and faster changing than academia. Industry is beset by many changes such as social, technological, scientific and economic. These changes have affected all areas of life, including engineering, and the engineering faculties have to respond [6], [7].

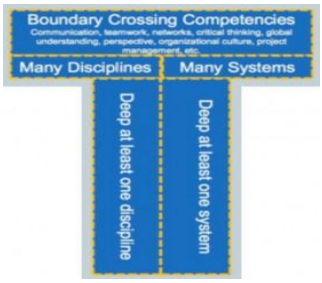

Figure 1: T-shaped graduates needs [5]

II. THE T-SHAPED ENGINEER AND THE TECHNOLOGICAL REVIVAL

Technology is currently undergoing a true revival. However, for this renewed appreciation to be a success, it is vital that the new technician is T-shaped. The engineering community has embraced the T-shaped concept as an ideal method to prepare practicing engineering graduates for the global economy. Such training prepares professionals for success negotiating the corporate, global world of industry. We can find the usefulness of the T-concept everywhere. While the engineers are out in front on this concept, every field will require T-professional development [4], [8].

Companies employ graduates for their core technical depth. Most organizations in their graduate trainee programmes spend a fair amount of time and effort with recent graduates integrating them into teams and coaching them to be effective in what is rapidly becoming a more team-oriented environment. The skills needed to be impacted on the students by the engineering teachers during their five-year programme are shown in Figure 2. The total students need to combine the technical expertise with the entrepreneurial and management skills. The resulting engineers with entrepreneurial attitude, innovative mindset, knowledge of changing trends and leadership and management skills with deep technical skills would produced.

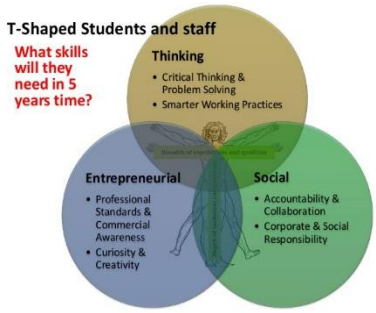

Figure 2: T-shaped students and staff [9]

III. WHAT ROLE DO UNIVERSITIES PLAY IN DEVELOPING WORK-READY, T-SHAPED PROFESSIONALS?

The big problem is that universities are producing more generalists than specialists and it's becoming harder and harder to be a specialist. Thus, becoming a specialist means very hard work and constant improvement, a task they have to undertake on their own**.** Universities, traditionally, create professionals who are specialized in one specific domain (I-shape). Universities are now expected to do more to prepare students for the job. Universities should create opportunities in their educational system through which students can develop those skills as part of their academic achievement and come out of the universities better prepared [10]. A good start is emphasizing collaborative and hands-on experiences that give students a sense of the workplace [3].

Engineering program should produce the 'societal engineer' who not only has T-shaped skills, but can appreciate how such a shape can advance society.
This demand has spurred interest in exploring T-related solutions and best practices across the country. One response that seems to hold some
promise is the creation of more T-shaped professionals. It has been proven many times that a change in technology or market conditions devalues knowledge of I-shaped professionals but T-shaped professionals on the other hand have a lot of potentials.

Since 2004, IBM has been working with universities, governments, and industry partners around the world to advocate a new discipline called Service Science Management and Engineering (SSME). SSME seeks

to address the need for increased Science Technology Engineering and Mathematics (STEM) education to meet industry's need for more research-driven service sector innovation [11]. SSME helps create T-shaped professionals who are better collaborative innovators [7] and adaptive innovators [12] because of their deep problem solving skills in one area and broad communication skills across many other areas.

A university faces many challenges in equipping graduates with the right skills and attitudes that will make them employable. The shift from the predominantly manufacturing based industries to the service based one is a source of one such challenge. Focusing on the faculty of information science and technology, it is contended that there is a need to examine its current curriculum and methods of instruction so as to ensure that future graduates will be suitable for this new economy. In this position paper, based on the model of the T-shaped professional and drawing insights from the newly developed field of service science, management and engineering (SSME), it is proposed that a combination of approaches is undertaken in restructuring the curriculum so that future graduates from the faculty in particular, and the university in general, will be ready to face the challenges posed by the new era of services [13].

The creative way to achieve these is to break down the boundaries between disciplines so that students can have more versatile experiences, taking into cognizance the strengths and capabilities of the programmes across the university. A university with strong programmes in so many disciplines such as engineering, business, humanities, science and agriculture, has significant opportunities. If we want to increase the competitiveness of graduate students for jobs on a global basis, there is the need to integrate new and recent graduates quickly into business environments so they can demonstrate very quickly their value and their potentials. The T-shaped skills can really be a major differentiator [3].

The T-shape competency profile rejects a "one programme fits all approach". Students need to get the chance to develop individually in the various components. However, all students should develop their T-shape during their time at university. Developing a T-shaped curriculum cannot be the sole responsibility of one program or specialization. It should be a coordinated effort of various team players, where the team leader should be a specialist with a general view and integrative skills (ideally a person with a well-developed T-shape profile). Development and implementation of T-shaped curricula should be part of strategic education policy of the university [4].

The current system of education lacks connection and interaction between different industries, which is something our ageing society will desperately need in the future. People who are talented, professional, caring and full of creative spirit to invent or design products and services for the elderly are needed. The new learning model called 'T workshop' in higher education uses multidisciplinary approaches to cultivate 'T-shaped' professionals, elites who interact and cooperate with a wide range of disciplines and fields for the benefit of an aging society. The goal of increasing the communication skills by gathering participants from different backgrounds to solve a problem as a team with some professional help from the instructors and teaching assistants was met. This kind of T-shape cultivation would help break down barriers between different professionals and increase the possibilities of multidisciplinary cooperation or interaction. It will also help provide more opportunities and possibilities of a better life for ageing societies of the future [14].

IV. WHY SHOULD NIGERIA REFOCUS VOCATIONAL EDUCATION IN THE 21ST CENTURY?

Calhoun and Finch [15] reported that vocational, technical and technological education should always been refocused to satisfy the changing needs of people and society. Nigeria nation presently has many social and economic problems and most Nigerians are just recovering from chronic case of neglect and negative attitude towards vocational, technical and technological educational system [16]. The nation and her citizens are in the twenty-first
century questioning the quantity and quality of these aspects of education in the nations system of education and among Nigerians, especially among the youths.

If public education that is meant for everybody cannot prepare citizens for work, who else can do it? The neglect of vocational and technical education in the country has increased youth unemployment. Refocusing of Nigeria's through relevant vocational education programmes will in no distant time make the problem of youth unemployment and poverty among adults become outdated Despite the country's abundant resources, Nigeria had continued to manifest abysmal industrial performance record over the years because of the country's inability to synergies its resources to spawn an organic productive sector capable of engendering sustainable development and alleviate wide spread poverty [17].

The state of Nigeria's low level of industrialization is heavily dependent on her ability to come up with a competent and dedicated workforce [18]. The lack of dedicated and competent workforce is Nigeria's headache and the most militating force

against the nation's technological, industrial and any type of national development. Vocational and technical education at this point stand very tall in helping the nation get out of the problem of lack of appropriate manpower and therefore, needs just refocusing to produce the desired result [19], [20]

Ihinmoyan and Haruna [21] reported the current educational system is deficient in providing the necessary impetus for development. Nigeria's efforts at educational reforms and restructuring are aimed at focusing on redesigning curriculum, increasing funding, refocusing monitoring process, accountability and transparency to ensure effectiveness and sustainable national development.

A strategy for refocusing vocational education in Nigeria is by ensuring equality of access to vocational education by all Nigerians through modular curriculum for this aspect of education in Nigeria. The academically strong persons through further training at a tertiary education institution take all the prescribed modules in an occupational area of interest, become professionals and grow up to occupy leadership positions in their chosen occupations.

The academically weak persons are in no way kept out of the programmes but allowed to develop according to their abilities. This will ensure an array of categories of workforce for national development.

V. NATIONAL UNIVERSITIES COMMISSION (NUC) BENCHMARK MINIMUM ACADEMIC STANDARDS (BMAS) FOR AGRICULTURAL AND BIORESOURCES ENGINEERING PROGRAMME [22]

The Department trains students with broad-based knowledge of various aspects of Agricultural and Bio-resources Engineering thereby producing practical-oriented graduates with skills that are needed in mechanized agriculture, on-agro-resources and off-agro-resources storage as well as primary and secondary processing of agro-resources products. Graduates of the programme are also to possess the requisite skills for all such activities that enhance the preservation and conservation of natural and environmental ecosystem.

The objectives of the programme are to:

1. teach the students the basic scientific principles in solving technological problems of agriculture and food production by providing them instructions in analysis, development, design and practical work in the various branches of agricultural engineering;
2. provide a thorough foundation in the basic physical sciences, applied agricultural sciences and engineering fundamentals;
3. exposing them to a lot of laboratory and field exercises that will make them tackle challenges in the field;
4. train the students to acquire the capability for meaningful result-oriented research in agricultural engineering.

The curriculum, which is compliant with the minimum academic standard of the National Universities commission is a five-year programme with the following categorization in Table 1.

Figure 3 illustrates the T-shaped Agricultural Engineer Model. The components of the system include mastery of a discipline,trans-disciplinary

Table 1: Categories of curriculum components

S/N	Category	Units
1	General Studies	16
2	Basic Science	26
3	Basic Engineering	46
4	Core Courses	88
5	Electives	12
6	Student Industrial Work Experience (SIWES/SWEP)	07
	TOTAL	195

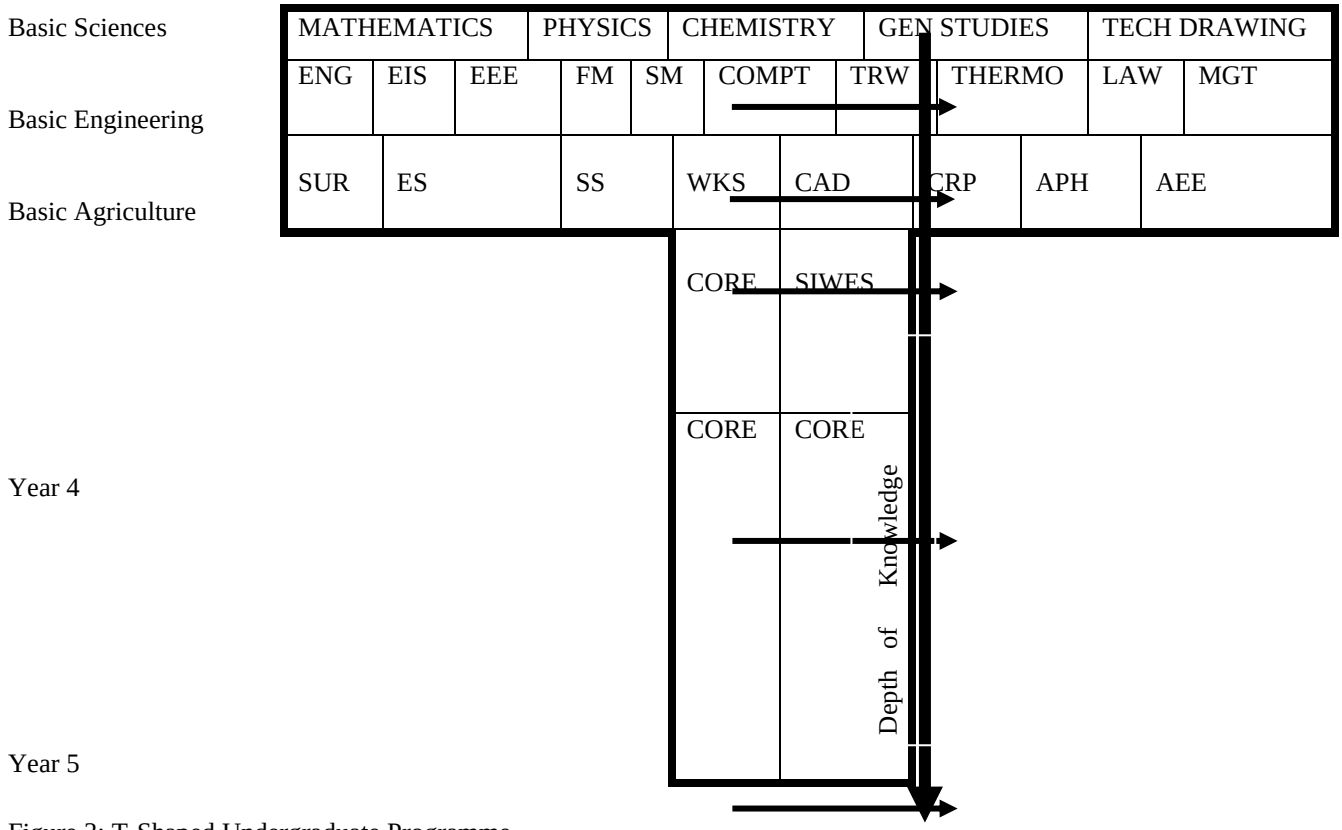

Figure 3: T-Shaped Undergraduate Programme

KEY:
ENG-Engineering Mathematics, EIS-Engineers in Society, EEE-Electrical and Electronics Engineering, FM-Fluid Mechanics, SM-Soil Mechanics, COMPT-Computer programming, TRW –Technical Report writing, THERMO-Thermodynamics, MGT- Management, SUR-Surveying, ES- SS-Soil Science, WKS-Workshop, CAD-Computer Aided Design, CRP-Crop Production, APH-Animal Production and Health, AEE-Agricultural Economics and Extension

knowledge used in the system, mastery of additional systems (as T grows), boundary crossing skills, and ME (knowing who I am and where I want to go).

This approach in Figure 3 fosters individuals with a deep technical understanding, the stem of the T, in the core subjects of the programme coupled with broader knowledge, the top of the T, in the basic science, fundamentals of engineering, computer technology, engineering design, innovation and creativity, law, management and entrepreneurship, technical report writing and communication and leadership.

The engineering undergraduate curriculum promotes the development of the complete "T". The individual have a breadth of knowledge stemming from undergraduate studies followed by a broadening of the depth of knowledge that will increase his/her specialization expertise at the Masters level and even deeper at the doctorate level. The approach offers a broad working knowledge, coupled with expertise in specific areas and fosters success in a chosen industry. Career

experience strengthens the T-shaped education, adding layers to both expertise and workplace skills, cultivating maturation into effective leadership [4].

Most people say that mathematical proficiency and technological expertise are the most important crucial skills an engineer needs. But as the demand for engineers has grown (the labour market is expected to increase by 11 percent over the next 10 years), so have the expectations of employers of labour [9]. For future engineers, developing T-shaped skills could make all the difference in attaining a successful career following graduation.

Many companies, including IBM, are anxious to recruit T-shaped engineering students, expecting them to solve problems in their technical fields within the context of the entire organization. These students will be in high demand when they graduate and apply for jobs. In addition to IDEO and IBM, companies such as GE, Proctor & Gamble, and Nike all embrace the idea of employing engineers with T-shaped skills, and training their engineers to have these skills as well. We need T-shaped graduates who can work well together to co-create solutions for a smarter planet [23].

The industry is moving towards a T-shaped model, but universities are slow to do the same with their curriculums. Most universities educate engineers to
become the equivalent of bricklayers, rather than
cathedral builders [24]. Universities and colleges are rising up to this big and growing challenge with the development of various programmes. Lehigh University program in Integrated Business and Engineering (IBE) prepares students for leadership roles in industrial R&D, entrepreneurial initiatives, management consulting, high-tech ventures, innovative technology, and financial services.

Boston College engineering program creates the 'societal engineer'; an engineer who not only has T-shaped skills, but can appreciate how such a shape can advance society. The Oregon Engineering and Technology Industry Council (ETIC) invested $29 million fund in Oregon Universities to increase T-shaped learning in addition to giving special priority to grant proposals that promote solutions to the T-shaped challenge [9].

Countries across the globe accepted the calls for sweeping structural and cultural changes in engineering education, including a shift from disciplinary thinking to interdisciplinary approaches and increased development of teaming skills as a means to stay competitive and produce better engineers in T-shaped skills. Researchers believed that the growing gap between engineering practice, education, and research is a cause for concern and one of the keys to equip qualified engineering students is to help them learn about engineering in context; giving adequate opportunities for both deepening and widening their knowledge base and for learning all the necessary skills.

Industries has a great role to play in accepting to develop these engineering students during their six-month SIWES programme in year 4, accepting them to participate in the National Youth Service Corps (NYSC) also after graduation and more important also by contributing to the facilities, Research and Development and training while in school. Education for innovative engineering requires an active, committed and knowledgeable participating supervision, which might be expensive in time and required expertise, but gives a huge return on investment in the end [25].

There are close relations between the companies and our universities. Thus, research programmes are calibrated in relation to the possible need of external recipients of the research and of the doctorates [26].

Our world is changing and changing rapidly. There is need for a 21st century classroom where the 3 R's (reading, writing and arithmetic) meet the 4 C's (creativity, critical thinking, communication and collaboration) and all students are prepared to be active participants in our exciting global community [27].

VI. CONCLUSIONS

The transition from University life to the world of work requires substantial application and attention in the development of various curricula for a better and ideal graduate engineer.

The task for those involved in the professional development of engineering graduates in the 21st century is to ensure that learners are given adequate opportunities for both deepening and widening their knowledge base and for obtaining all the necessary skills, with an entrepreneurial flair and a genuine concern for the environment.

There is therefore the need to revolutionize the entire education system by fusing the three Rs together with the four Cs (critical thinking and problem solving, communication, collaboration, and creativity and innovation) in the future engineer.

T-shaped professionals and especially engineers as urgently needed to improve performance in rapidly changing

knowledge-intensive organizations and networks of organizations.

Becoming a really well-shaped and strong T in life is basically a lifelong process that demands constant improvements, hard work and finding a balance between acquiring general and specific knowledge.

The Agricultural and Bioresources Engineering curriculum has the potential to create a T-shaped graduate agricultural engineer.

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On Capacity and Quality Issues in Engineering Studies across Sub-Saharan Africa: a Review

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***Abstract* - This paper highlights the challenges of 21st century engineering studies and practice relating to infrastructure growth in Sub-Saharan Africa (SSA). Tertiary education in SSA is experiencing explosive growth of 8.6% driven by the higher education institutions (HEI) of which the private sector accounts for 22% of enrolments. The unintended consequences have been the escalation of capacity deficits and quality problems in engineering studies. Capacity deficit for the SSA has also been exacerbated by brain drain and severely small pool of highly qualified academics. The causes of these issues are discussed while considering University as the centrepiece for development of appropriate remedial measures.**

Among the remedies to quality and capacity deficit issues in engineering studies and practice are: setting up internal quality assurance systems and rigorous implementation of accreditation requirements, promoting inter-Africa university collaborations, research networks in engineering, and advanced engineering degree programs. It is known that some of these initiatives are already operationally active in some disciplines but not adequately so in engineering.

***Keywords* – Quality, capacity, engineering education, Sub-Saharan Africa, Infrastructure, accreditation, research networks**

I. INTRODUCTION

Among most African countries, the contribution of engineering to economic development, sustainability and poverty alleviation has generally been overlooked or sidelined while attention is paid to basic societal needs such as health, environment, food, water and sanitation at community levels. While the significance of these various basic needs is certainly undisputable, it may be appreciated that engineering is an underlying essential element for sustainability to be achieved in most of the developmental programs, and absence of an endogeneous engineering capacity undermines long-term development. Such has been the past experience with most programs in developing countries. In the past 50 years, trillions of dollars in International Aid have been used in Africa but it is now common knowledge that Aid has failed to improve Africa's economy. It has been found that the poor who received Aid have not seen much betterment in human welfare than those who received little or no Aid [1]. It is important to realize that engineering is an essential discipline, that addresses challenges associated with alleviation of poverty and innovation for sustainable development. The engineering and infrastructure field, for example, contributes to these societal needs by:-

- Providing physical infrastructure needed by businesses, financial institutions and rural communities to conduct economic activities such as agriculture, trade and industry
- Raising productivity of local industries to enhance self-reliance and high value product chain capable of promoting industrial competitiveness for economic transformation
- Reversing the current technical brain drain which flows from rural to urban areas, and from developing to developed countries, through creation of employment opportunities such as labour intensive approaches; enterprise development, research and innovation

II. BACKGROUND

The role of engineering in development is evident from examining emerging economies that have made progress in economic development and poverty alleviation. It has been shown that the most important factors responsible for rapid economic transformation in these countries have been, *firstly* the creation of large basic infrastructure, promotion of enterprise development along with a pool of technical personnel for operation, repair and maintenance of enterprise industry, and *finally*, government support and funding of higher education institutions including technological and engineering sciences.

It is recognized that lack of adequate, quality infrastructure and its operational maintenance is one of the key factors that has hindered sustainable development in Africa. Poor infrastructure is a two-pronged problem, partly being a question of physical works of engineering, and partly being shortage of engineering capacity and technical competence. The problem is compounded by technical brain drain of the limited engineering capacity from developing countries to developed countries as a result of enticing opportunities offered to attract technically qualified personnel to sustain the developed international economies. This scenario in itself reinforces the known experience that technical and scientific

personnel are indispensable in developing new economies as well as sustaining full grown economies at any one point. In most developed countries, the engineering skills present are continuously assessed to ensure adequate availability of required professional skills while identifying any presence of possible skills gaps to be filled either through domestic training or scouting of highly - qualified foreign engineering personnel to be offered immigration visas. This is related to the nature of modern economies, being primarily industrial driven and represented in terms of the gross domestic product (GDP). Attempts by various African countries to attract investments is sometimes hampered as investors point out existing infrastructure and capacity as one of the major criteria in deciding their investment destinations.

Among the important physical infrastructure are transport networks including roads, railways, water, air, ports; energy and electricity infrastructure such dams; water, sanitation and irrigation systems; housing and buildings for end users such as hospitals, schools, recreation and sports, offices, hotels. Infrastructure is a critical intermediate input to the end product but it is also foundational to technological development and human welfare services. Agriculture, health and medical services, water supplies, education services, among others are to a great extent dependent on physical infrastructure. Good roads and bridges are critical agents for rural development in various ways; they enable trade of goods to and from remote communities, facilitating income generation. Good road networks reduce the communing time of workers, in turn improving productivity. It has been suggested that poor roads cause more adverse effect on the economy than the impact of good roads. Innovative engineering design of houses and modelling of landscapes can be applied to minimize mosquito breeding therefore reducing malaria the major killer disease in Africa. Dams for hydro-electricity generation are, in some African countries, the only source of electricity necessary for industrial activity as well as domestic use. Dams for irrigation projects are essential for both large-scale and subsistence agricultural economy, as well as livestock that sometimes are the main source of livelihood for certain areas such as the semi-arid regions. Furthermore, African countries are experiencing high population growth rates along with urbanization which is aggravating already existing poor and inadequate housing conditions. Governments and the private sector alike have not been able to develop adequate solutions and are faced with this ever growing challenge.

III. INFRASTRUCTURE AND THE ECONOMY

Infrastructure is considered to be the engine of economic growth [2]. In Sub-Saharan Africa (SSA), the crucial need for infrastructure as a necessary input towards implementation of programs for poverty alleviation and economic development is quite apparent as it creates local employment opportunities, re-distributes wealth with particular relevance to rural areas, and harnesses the power of science and technology for domestically developed innovations that provide solutions in problem solving.

Physical infrastructure is classified into the six categories of *energy, water management, transportation, communication, measurement networks*, and *waste management*. The main challenge facing African countries is creation of the required infrastructure and engineering capacity to serve the societal needs for development and economic growth. It is unfortunate that the change in stock of infrastructure in African countries over the past decades, does not correspond to the population and economic growth requirements, with demand for infrastructure exceeding its supply. It becomes further aggravating to realise that even the existing infrastructure tends to deteriorate rapidly, stemming from poor construction practices and lack of adequate maintenance, the hallmarks of dependence on foreign expertise and technologies with no local capacity. The significance of infrastructure is directly related to socio-economic growth of any country. The national income or GDP per capita of a country correlates linearly with its stock of infrastructure as shown in Fig. 1 [3]. It can be derived from the graph that a deliberate investment of any nation to increase its stock of infrastructure (and by implication its engineering capacity) will have a corresponding impact of increasing its national income, as a result of the roles that physical infrastructure plays in the economy. Compared to countries from other regions of the world, it is also clear that African countries have the lowest income per capita, confirming the disparaging levels of poverty already known to currently exist.

The extent of infrastructure deficits in Africa have been documented and compared, with those from low income countries (LIC) and middle income countries (MIC) of other parts of the world. Fig. 2 shows that SSA countries lag behind other LIC and MIC in all the different kinds of infrastructure. It can be seen that the largest gaps occur in paved roads, mainline and mobile phone coverage, and power generating capacity [4].

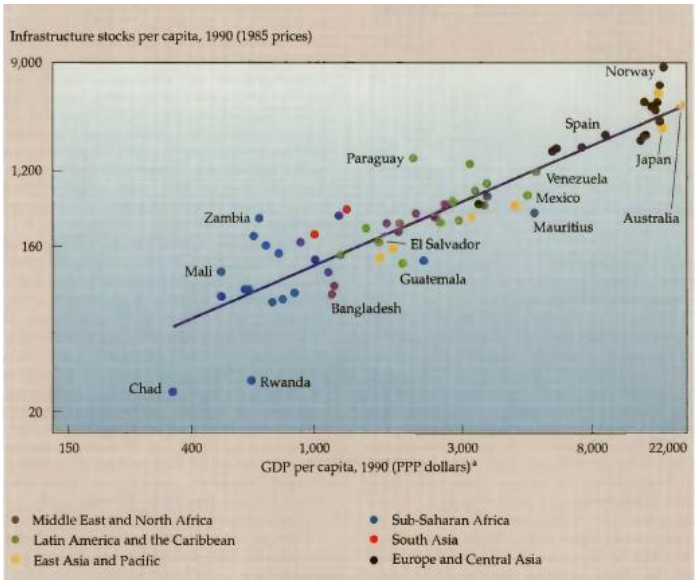

Fig.1 Relationship between economic growth and infrastructure [3]

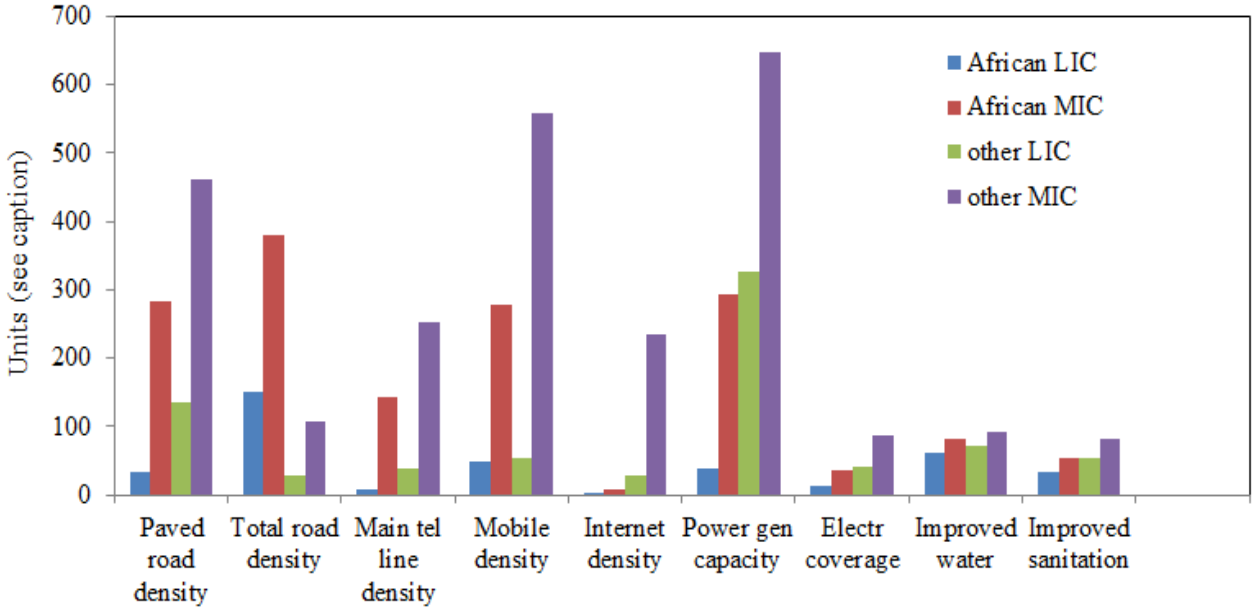

Fig. 2 Infrastructure deficits in Sub-Saharan Africa (Units: Road density in km /100 Km^2 of arable land; Telephone density in lines per thousand population; power generation capacity in megawatts per million population; electricity, water, and sanitation coverage in % of population); constructed from[4]

IV. HIGHER EDUCATION IN SUB-SAHARAN AFRICA

The SSA, an extensive geographical block consisting of 46 countries and an estimated population of over 973 million in 2014 (World Bank: http://data.worldbank.org/region/SSA) is relatively highly underdeveloped; it bares the shared historical paranoia of colonialism, pandemics, ravaging conflicts and diseases, which have contributed to high poverty and high mortality. Education is seen as the key to future growth and development in SSA. Studies [5] have shown that higher education in Africa is the lowest in comparison to regional blocks worldwide, as seen in Fig. 3. Evident in the figure is the strong relationship between per capita income and university enrolments. These observations are consistent with the findings of Moser and Ichida [6] showing that economic growth increases education enrolments. Indeed the latter reported that 10% per capita increase in GDP leads to increased primary education enrolment of 3 to 4%, 1% increase in life expectancy and 4% reduction in infant mortality. Higher education in SSA is generally being recognized as an important sector in driving economic development [7]. Fortunately, recent trends in tertiary education in SSA are reported to be showing remarkable increase. UNESCO [8] reported an average of 8.6% growth in HEI enrolments between 1970 to 2008 compared to a corresponding growth of 4.6% globally. It is depicted that SSA is playing accelerated catching up in higher education. Between 1990 to 2007, the number of public institutions is reported to have doubled from about 100 to 200 while the private sector HEIs have grown much faster from 24 to 468 institutions, a growth of 1850%. Francophone countries such as Senegal (41 HEIs), Democratic Republic of Congo (39 HEIs) account for 53% of all enrolments, while Anglophone countries had enrolments of only 34% [9].

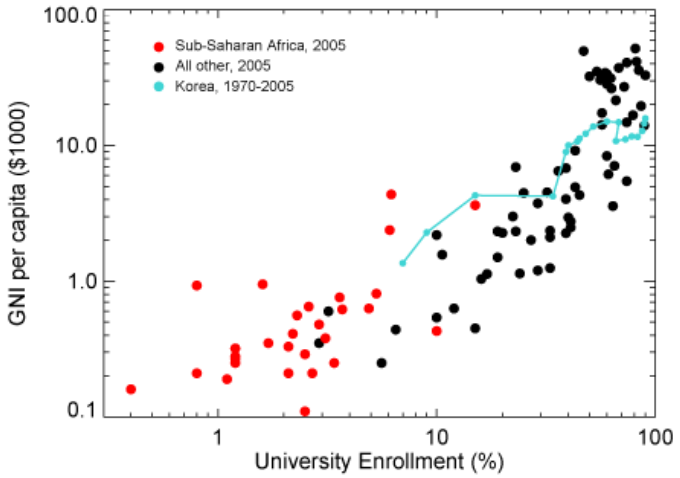

Fig. 3 University enrolments in Sub-Saharan Africa [5]

Public HEIs hold a prestigious position and occupy top rankings in the continent, while private HEIs appear to somehow play a backup role to absorb students who cannot gain access to public institutions [10]. Despite the current significant growth in enrolments, it is reported that only 6% of eligible age group is enrolled in HEIs in SSA compared to the world average of 26%, as seen in Fig. 4. The 6% enrolment lags all global continental blocks whose enrolments are 70, 84, 38, 25/26, 21, 13% respectively for N. America/W.Europe, E. Europe, Latin America, Asia/the pacific, Arab states, S/W. Asia. More recent data shows that SSA student enrolments in HEIs rose to 8% but remains relatively dismal compared to other world blocks. Engineering education enrolments can be expected to be much less and in dire need of improvement [11]. de Villiers and Nieuwoudt [12] discuss the global trends in higher education pointing out the shift that appears to be occurring from *elite* systems which have enrolments of only about 15% among the eligible age group to *mass* systems which accommodate 15 to 50% enrolments.

In some ways, these global trends appear to be affecting SSA enrolments positively by way of influencing deliberate policies to strive towards expansion of higher education in the African sub-continental block. Two of the main factors that are thought to be responsible for recent increase in enrolments at higher education in SSA are the policies leading to mass increase in primary and secondary education such as the "universal primary education" policy etc. and the privatization of higher education. It is reported [13] that in 2006, private higher education was responsible for 22% of enrolments in HEIs in Africa. But factors associated with affordability of higher education across the continent cannot be neglected, as earlier underscored in Fig. 3.

V. CHALLENGES OF ENGINEERING STUDIES AND PRACTICE

Given a favourable socio-political and economic environments, the crucial technical issues relating to engineering studies in SSA fall into the two categories of *quality* and *capacity*. While the capacity aspect is an endemic problem in SSA that has existed predominantly from the times of colonisation, poor quality appears to have taken on a new level directly as a result of expansion of the current education system, through the free enterprise of the private sector institutions.

A. Escalation of quality problems in engineering studies and practice

As already mentioned above, the general enrolments in HEIs are growing but still lagging, with the actual enrolments being only 6% in SSA relative to the 26% world average. An article by Mohamedbhai [11], summarises the main issues associated with quality, including the use of outdated curricula often "copy and paste" from Western countries, which may not appropriately serve the practical needs of Africa. The lack of adequate and cutting-edge facilities such as laboratories for practicals and experiments, highly undermine relevant teaching. Modern teaching methods require use of in-class and out-of class technologies, which allow speedy coverage and distribution of course contents to students. These include the use of projectors, internet based-teaching, online approaches. The limited availability of reliable telecommunication infrastructure among African universities i.e internet networks etc. is a major bottleneck to implementation of technologies in teaching. Although, these issues have long existed traditionally among African universities, they have been aggravated by expansion of the education system. There is now a perception that the explosive growth of HEIs in SSA is occurring at the expense of quality of program delivery. Evidence of these core quality problems have been observed across SSA [11,14]:-

- Non-accredited academic programs: The absence of sufficiently qualified academic staff, poor curricula, and inadequate infrastructure has seen rejection or withdrawal of accreditation from universities offering engineering programs. This has occurred in various countries including Nigeria, Kenya and other SSA countries. In Kenya for example, only 25 of the 70 engineering programs offered in the country, are accredited.

- Registration of practicing engineers: Many graduates of engineering programs in SSA are practicing without acquiring professional registration from the appropriate

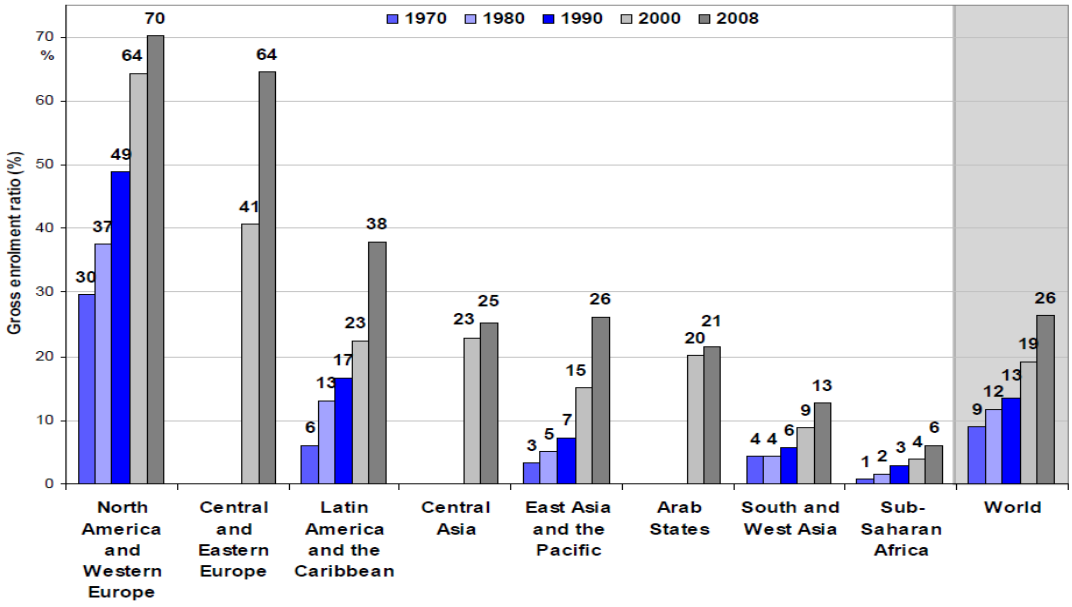

Fig. 4 Comparison of gross enrolments worldwide [8]

governing body, such as the national Engineers Registration Board (ERB), for example. This problem is partly related to non-accredited engineering programs, whose degrees cannot be recognized. Indications are that only 25% of applicants to the ERB in Uganda are granted registration status.

B. Engineering capacity deficit in Sub-Saharan Africa

Delivery of infrastructure in SSA is largely characterised by inadequacy of local capacity to supply technical capabilities required for project implementation at all its stages from planning, design, construction, and operation. In most cases, local construction firms may be able to handle small project works while leaving large construction projects to the employ of international consulting and construction companies due to lack of local capability for large project works. Capacity deficit is related to the critical underlying issue of training for engineers and technical personnel [3]. The gravity of lack of high-level engineering skills among African countries is known to be of a very high scale as shown in Table 1 [15]. The population served by a single engineer in Africa is up to 13,000 persons compared to 100 to 300 persons in most developed and emerging economies. For example, one civil engineer in local government in South Africa serves a population of up to 33,000. Again, these numbers can be higher for other African countries [16]. As discussed earlier, engineering capacity deficit is compounded by technical brain drain of the already limited engineering capacity in SSA.

C. Higher qualifications and academic research

In addition to the primary role of universities in providing graduate and postgraduate degree training, basically developing high level human capital necessary for economy, HEI's are also research and development centres for industry, serving the purpose of incubating research ideas that can be turned into industrial products and services. HEI's have also become agents of community development and often work closely in partnership with industries towards achieving sustainable development [1,17].

Although the number of HEI's in Africa have grown considerably in numbers and enrolments, engineering education in particular faces considerable difficulties:- there is shortage of qualified teaching staff partly as a result of the small pool of locally available graduates and due to unattractive salaries. It is usual for a lecturer to leave a university career for better paying positions in government civil service or private sector. For lecturers who continue with university careers, it is common for some to have other work places for generation of additional income, thus sharing out their time which would otherwise be solely devoted to the academic institution.

There is also low level of research output in SSA and poor connectivity to global knowledge. The lack of research is partly linked to inadequate research facilities and funding as well as severely inadequate number of highly qualified academics. A large proportion of academic staff in African universities do not have higher degrees at master's and PhD levels. For example, in Rwanda's HEIs, the number of science lecturers with PhD and Masters level degrees were only 24% and 45% respectively, while the rest had only first degrees or less [18]. It is not surprising to find that most African HEI's have few or no master's and PhD level degree programs, due to lack of necessary teaching capacity, most especially in engineering and sciences.

TABLE 1
COMPARISON OF TRAINED ENGINEERS FOR AFRICA AND OTHER CONTINENTS [15], (*REGISTERED ENGINEERS ONLY)

Country	Population per Engineer	Country	Population per Engineer
Norway	122	Australia	455
China	130*	Hong Kong	463
Finland	136	Malaysia	543
India	157*	Chile	691
Greece	172	Poland	748*
Denmark	179	Singapore	1,341
Canada	179	Korea	2,135*
Sweden	209	Hungary	2,214
Germany	217	Romania	2,909
Brazil	227	**South Africa**	**3,166**
Iceland	280	Sri Lanka	5,595
France	276	**Tanzania**	**5,930**
Ireland	280	**Namibia**	**6,346**
Japan	303*	**Zimbabwe**	**6,373**
UK	311	**Swaziland**	**12,238**
Argentina	453	**Zambia**	**12,783**
USA	339	**Ghana**	**12,992**

VI. REVERSING DEFICITS AND PROBLEMS

The University is central to reversing the current trends and deficits identified in engineering studies. But this can only happen through deliberately planned initiatives intended to address these issues with practical and measureable outcomes. Some suggested strategies that may be employed are discussed:

- Establishment and implementation of quality assurance (QA) systems in HEIs. These are needed to improve the quality of programs by ensuring that universities conduct their own internal quality assessments. However, this occurs as a university-wide QA system. The program specific QA system, administered by industry boards such as the ERB, is also extremely important. In SSA, however, such professional based QA systems do not presently exist except, in very few countries such as South Africa where the Engineering Council of Southern Africa (ECSA) is tasked with national accreditation of professional engineering degree programs.
- Training of Africans by Africans in advanced academic studies: This concerns the current shortage of academic staff in most African universities, and its association with lack of sufficient research output in engineering. There are currently very few universities that offer high quality engineering course programs at master's and PhD

postgraduate levels. Collaborations among African universities can be focussed to locate existing programs and/or assist to develop relevant advanced programs in HEI's within engineering and infrastructure fields.

- Mobility: The mobility of HEI staff and students within SSA sub-continental region can be one of the most instrumental vehicles which can allow specific arrangements to be established for cross-linked undertaking of high quality academic studies, teaching, research, and training. In so doing, several benefits related to strengthening and capacity building can be achieved at institutional, national, regional and multi-lateral levels through active partnering amongst HEI's [19].
- Harnessing of brain gain, circulation and knowledge flows: Deliberate effort is needed to scout potential African students who are in the diaspora. These candidates can be engaged and supported to participate fully in Africa's development in an effort to counteract brain drain and achieve brain gain. Also, academics and professionals in the diaspora can be engaged to contribute to course programs at African universities, in areas such as curricula development, delivery of guest lectures etc., amongst others.

VII. SUMMARY

Engineering studies and practice are an indispensable part of the growth trajectory for the 21st century infrastructure in Sub-Saharan Africa. The sub-continental block, which is underprivileged and lags behind all other regions of the world in development, needs to amass a high stock of infrastructure. Consistent with this need, is the necessity to develop and sustain strong engineering capacity of high quality.

It is essential that the present growth in higher education is sustained, while engineering capacity deficits and quality problems must be contained. Measures are discussed which may contribute some remedies, including: establishing quality assurance systems and intensifying accreditation requirements for engineering degrees, collaborations to provide advanced degree programs with other nearby African countries as opposed to travelling overseas, enhancing the inter-Africa mobility of students and staff to undertake academic programs, mitigating brain drain and reversing the trend to brain gain. Some of these measures are already in place but need to be enhanced. Each country needs to know the required number of engineers and technicians at a national planning level, and then set up strategies and action plans to achieve these requirements.

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The Role of Context in Decolonising Engineering Curriculums in Proudly South African Universities: A Cybernetic Perspective

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Abstract **- This paper addresses the epistemological challenges facing South African Public Universities in light of the *#FeesMustFall* campaign and the associated outcomes. Of particular interest are the academics who are to embrace the changes while they remain in the education system. The decolonisation of knowledge, which is still not clearly understood nor agreed upon, necessitates a rapid review of the status quo in the major universities and how they conduct their business. While transformation and decolonisation are not synonymous, the universities will be undergoing transformation to address the decolonisation needs of the majority of its students, which has already created dilemmas for the academics who have largely followed a Eurocentric approach, and are now to implement the changes addressing decolonisation. The immediate aspects facing the academics are the undefined curriculum changes, as well as the new teaching and learning strategies, which need to reflect the epistemology of the students addressing an Afrocentricity that has not been embraced in the past. A cybernetic perspective relying on Pask's Conversation Theory may be integral in allowing the academics the skill to contextualise the curriculum, embracing those who are the consumers of this new co-created locally generated knowledge.**

Keywords **- Conversation theory, cybernetics, contextual approach, decolonisation of knowledge, South Africa**

1.1 Contextualising the Paper

In October 2015 a student led campaign called *#FeesMustFall* formed as a response to tuition fee increases at South African public universities. These public universities account for 89% of all tertiary level enrolments [1]. The student demands also included the decolonisation of knowledge in these universities. This and earlier protest movements highlighted the inherited legacies of the apartheid regime and the need for transformation. The talk of decolonisation of knowledge is not new in South Africa though. Mahmood Mamdani [2] noted that without an Africa-focused Intelligentsia, the challenge facing South African universities will remain. Du Toit's [3, p94] view was that South African universities were facing grave challenges with "the enduring legacies of colonial dependence and the colonisation of consciousness", published more than 15 years ago. However, the urgency for change is now at the forefront of the universities' and government's agendas owing to the mass mobilisation of the students who seek out the changes. The responsibility on academics at South African Universities is probably higher than ever before. Firstly, with the successful *#FeesMustFall* campaign, cost cutting mechanisms have been implemented and are probably here to stay throughout 2016 and the election year of 2017. The additional financial burden has seen universities take frugal measures to curb spending, including reducing budgets for hardware, travel, staff hiring, and so forth. These challenges are to be dealt with by university management who need to plan for minor increases for at least two years. However, the even bigger challenge facing academics rests on the probable revolution of how the curriculums are to be presented in terms of the decolonisation of knowledge that the students (and some parents, staff and other professional partners) would like to see. From the outset one should know that South African universities are not facing a top down governmentally organised re-curriculum agenda to replace the current worldview with a defined African world view. There is however political pressure to embrace transformation; however, the space is open for discourse and ideas amongst role players, but for the most part, this responsibility rests on the academics and students who share the conversation spaces in the classrooms.

Teaching and learning are obviously critical aspects of universities; however, in South Africa this area is often measured by management according to student intake size, throughput, and pass rates. The role of research is increasingly important in the public universities, especially since university rating agencies emphasise this when ranking the universities. Further, the funding model favours the research aspects of the public universities to such an extent that even the former Technikons, which were mostly geared for teaching and learning, have either been merged with universities or adapted to become research centres as well. Proof of this priority to increase research output is evident in the high growth in publication output that has more than quadrupled in South Africa from 1996 to 2014, with South Africa sitting in 34th place in the world journal publication rankings [4]. A problem

has occurred in that teaching and learning tends to be less valued and acknowledged than research outputs, even in global spaces [5]. Thus, the shift from teaching to research has also resulted in shifts in the staff complement. This further defocusses the requirement for teaching excellence when the measurement of this core aspect is firstly, difficult to quantify, secondly, difficult to achieve, as many academics are specialists in their field but not necessarily specialists in teaching. Lastly, some academics who may prioritise teaching development spending much time on this aspect, do so at the expense of a lower research commitment, even at the risk of their career [6]. In keeping with international trends, improved student experiences in universities, including the new motivation for improved teaching practices, are also the buzz in the South African context. Faculties now need to show that they have a teaching and learning focus, which is especially true in the engineering faculties whose staff mostly have not had the same exposure to the humanities courses and the methodologies that are closer to this arena of teaching and learning.

The requirement for transformation in the university, especially at ground level —the classroom— leaves many lecturers in a challenging position. The new focus on teaching and learning impacted with the decolonisation of knowledge in the curriculums is a tall order to fulfil. Many lecturers are lost as they do not have the tools/skills to adapt to a new fluid approach in teaching, which itself has not yet been defined. This uneasiness in the academic circles is understandable, especially since this teaching shift has not been a requirement before. Further, this coincides with a perception change in the importance of the student as a customer, shifting the focus from the teacher to the learner and the learner's experiences.

The decolonisation theme is not a superficial requirement. Removing statues, changing the wording of the mission statement, re-compiling the university website and marketing material, are just the tip of the ice-berg. Decolonising the colonial legacy has a wide scope. For example, the faculty subdivisions, degree names, tuition languages, even the physical design and layout of the universities are colonial with many South African universities being over 100 years old. To enable the successful transformation, the staff need to embrace the transformation and in the end too need to transform. This is a daunting process as it relies on integrating new worldviews and methods into one's own way of seeing and experiencing the world. A cybernetic approach is presented as the means for change, allowing for a contextual approach to addressing transformation in teaching, learning, and curriculum design.

1.2 A Cybernetic Approach

This section was added for the reader who is not familiar with cybernetics. Cybernetics is not easily defined. There are at least two reasons for this. The first reason is that cybernetics does not have a home discipline. Pask [7, p11] states:

> Cybernetics… like applied mathematics cuts across the entrenched departments of natural science; the sky, the earth, the animals and plants. Its interdisciplinary character emerges when it considers economy not as an economist, biology not as a biologist, engines not as an engineer. In each case its theme remains the same, namely, how systems regulate themselves, reproduce themselves, evolve and learn. Its high spot is the question of how they organize themselves.

With such a diverse spread of cyberneticists and their subject areas, it is difficult to define the "what is…" to a simple question of what is cybernetics. The Greek word *Kybernetes* translated into English is *pilot* or *steersman*. The term cybernetics was coined by mathematician Norbert Wiener in 1948 and was described in his book *Communication and Control in the Animal and the Machine*. In Weiner's model, cybernetics adheres to the laws of physics. His view of cybernetics had limitations but from his coinage, the path had been laid for increased scope of cybernetic thinking, specifically at the Macy Conferences (1946 to 1953) where new themes were introduced, including patterns, regularity, and feedback, which translated into circular causality [8, p178]. With the awareness of the observer in systems, a new chapter of cybernetics emerged: second order cybernetics. This brought the observer into the system. The observer needs to be accounted for. For example, anthropologist, ethnographer, and cybernetician Margaret Mead [9], who studied people and their cultures realised that her mere presence in their company was impacting the behaviours she experienced. In Mead's case, whether it be that the cohort acted differently to impress her, please her or even anger her, her presence altered what she observed—the observer effect.

With the growth in constructivist narrations, observer dependent realities and recursive relationships, so too did cybernetics evolve. Many cyberneticians are also constructivists and vice versa as there is some overlap, particularly in Glasersfeld's [10] radical constructivism and the theme of reflexivity. Cybernetics is vested in principles that are used to formulate a cybernetic understanding of phenomena. One reason for introducing cybernetics in this paper is to frame the decolonisation as one that is not separate from those who view it, discuss it, and live it. This means that all role players under the university umbrella are connected to this issue of decolonisation. This addresses the cybernetic view of being an observer *in* the system. By acknowledging that transformation is a shared problem, the ideas of epistemology, mutual causality, and reflexivity arise. From the outset, one should know that it is easier to experience cybernetics as a worldview rather than as a model, for modelling something seeks to create the separation between the model and the person who invents it owing to the objective nature of the definitions of such model [11]. This relates to the second reason for why defining cybernetics is troubling. The definition of something is tied to the observer who punctuates the distinctions figure from ground. We are all inhabitants of different linguistic domains,

which also have their own way of knowing and understanding the world through the vast works of mythical thinkers, poets, and their canonical texts that are relevant to these respective linguistic domains [12]. From a biological perspective, Maturana and Varela [13] explain how our experiences are mapped in our neurology, which in turn relates to how our thoughts produce our epistemology. Observations arise out of neuronal activity, which is a function of past neuronal activity in how the connections in the brain have been wired, for neurons that fire together wire together. Thus, the repetition, acceptance, and linguistic expression of cohort behaviours is what separates different groups from each other. From each linguistic domain the use of language, logic, and the justification for actions relates to the socially accepted formalised standards for each society. If two cultures are brought together as MacIntyre [12] discusses in his analysis of the Spanish and the American Indians during the colonisation of the Americas, the two different linguistic communities exhibit vast misunderstandings when interfacing with each other. Misunderstandings do not only arise owing to the lack of translatability of the two languages, but also due to the lack of common cultural norms and beliefs that can be implemented as baselines between the two cultures. For example, the Spanish believed in property rights while the Native Indians did not accept this concept, as who could own shared land?

MacIntyre proposes that if a person could inhabit both linguistic systems, they could have a better chance at integrating the two different linguistic communities. This person would find him/herself between two worlds where each worldview has developed an acceptable social reality and consciousness. Even with these individuals who have had this opportunity to inhabit two linguistic domains, there are still challenges in seeking a common ground between these two cultures. MacIntyre has successfully set the stage for a person to have a rational relativist response of "seems right to this group because of such and such", rather than being able to just dismiss the one group in favour of the other. Transcending this epistemological challenge for the role-players within the university will require tolerance, respect, and most of all, learning. Thus, it is an important step in the transformation process of the university and its staff, for people who are at least in part versed in both an African epistemology and a colonial one, to be actively involved. Obviously there is variety in African and colonial worldviews as they are not simply two items of uniformity. Ideally, if individuals could be identified who have lived in both a colonial and an Afrocentric culture, speaking and understanding the respective languages, these people could be instrumental in assisting in the new understandings that are needed for those whose ancestors are not African.

Being a South African but from Western origin who spends most of my time in shared linguistic spaces that comprise mostly of Black South Africans, I have realised that it is no longer acceptable to continue with the dominant discourse of a colonial legacy without at least the agreement of those who are mostly affected by it. In embracing the transformation shift in my classes, I adopted a contextual approach to tackle, firstly, my lack of understanding of the linguistic systems of the students in my class, and secondly, for the co-creation of a "do what works best" pragmatic approach in order for the students to achieve their goals in a system that reflects *their* epistemology. Lastly, aiming for the overarching goal of sustainability of the public universities in South Africa.

1.3 Why a Contextual Approach?

The issue of decolonisation arises out of the lack of transformation in the university structures. Lack of transformation means the dominant discourse and activities in the university do not reflect the majority of people who are using the system to achieve their goals. This includes the design of the curriculums; the dominant teaching and assessment approaches and how they are implemented; the reliance on imported knowledge for the curriculum content; the focus on the exportation of research outputs published in foreign countries; the disconnect between many staff and students both in the classrooms, as well as in the management spaces; and the lack of integration of the epistemology of the students into the university.

The reverse of colonisation is to break from a European perspective and emerge with independence in thinking, embracing the local majority view, whether integrating this epistemology into a hybrid summation, or what seems most probable, a continuously evolving approach of recursive improvements resting on the continuous feedback from student groups along the way. The latter is favoured owing to the time required for role-players to adapt, which includes learning new skills in teaching and learning and integrating these into the learning systems. The degree of decolonisation in the universities will ultimately depend on the needs of the people who require the change, moderated by the economic forces in a largely capitalist South African economy. With the large public universities acknowledging that resisting the transformation will see the universities tear at the seams, large scale transformation is imminent. Thus, the question is not whether the universities must decolonise, it is how they can perform this task with minimal social unrest, while still serving industrial partners.

Decolonisation is counteracted by incorporating those that require the change into the system to reflect the epistemology of this group, thus changing the system itself. How will the university know which direction to make shifts if there is lack of understanding as to what the needs of the students are? By contextualising the problems, deeper understanding of the students can take place in a respectful manner where there is openness to learning for the educators, students, and professional partners. The umbrella of role-players is wide and other interested parties may seek to be part of the conversation including parents, politicians, and most importantly, the industrial partners who are the receivers of the students that the university graduates.

It is obvious that for the universities to remain significant in their mission for academic freedom, the betterment of society, and education for the masses, they need to address the very needs of the bulk of South Africans. Using a contextual approach of allowing the students' voices to be heard and integrated into the university status quo diffuses the need for social unrest. The primary shared spaces in the university are the classrooms. Thus, creating and integrating students into the university will see this area having a central role in addressing the decolonisation requirement. The academics themselves will have to re-think their approach, addressing social justice in the classroom, while also steering the students into a direction that they will be prepared for the work environment upon graduation. This is a challenging tight rope which can be mitigated by contextualising the students' backgrounds, embracing these backgrounds, and most importantly, using these backgrounds as the context and curriculum baselines, which now may reflect the students themselves. There is thus a requirement for the personalisation of the learning outcomes, making the outcomes in the modules significant to the learners, addressing the learners' perspectives, while also tackling local South African aspects. For example, some lecturers have allowed for crowdsourced (student and/or community generated) assignment topics that the students partake in addressing the challenges in communities that the students inhabit. Whether it be engineering projects solving problems in the local community, including creating solutions for a local *spaza* shop operating with solar electricity, or a rural clinic not having cellular or ADSL service for electronic patient file transmissions to the regional hospital, or entrepreneurial aspects such as marketing and business leadership to informal or even small businesses. Students learning through servicing of their community while led by the skill of the lecturers—who should be specialists in the content of the learning outcomes—, allows for several aspects of decolonisation to be dealt with at once. The students still achieve their educational goals; the community benefits seeing the university as an important partner; the academics have a ground level experience of the needs of South Africans and the diverse cultures who inhabit the community spaces; all while the university achieves its goals of improved teaching and learning in the service of humanity. For example, the electrical engineering courses have an industrial project which each student needs to complete prior to finalising their degree. Instead of students building projects that are shelved, if all the students had the opportunity to only undertake projects that have a community involvement servicing a local need, contextualised learning is achieved in terms of the community needs. The project is then provided to the community or to the community representative who requested the solution. The student/s would need to work with the beneficiary of the project along the way to fully integrate the engineering solution. The lecturer also gains further contextual understandings of the communities, also bridging the relationships between university and community. Some of these projects have taken place with mostly good results; however, there are the social challenges of theft and so forth that do challenge the progress along the way. Additionally, the assessment methods can also be diversified while still meeting the local and international regulatory bodies' standards such as the Engineering Council of South Africa (ECSA), or the Association for Commonwealth Universities, who do not necessarily define the how of teaching and learning, rather they require the proof of the learning and the auditing security that the proof is indeed valid. There is already scope for community aspects in engineering, ECSA's exit level outcomes number 6 and 7 are intimately focussed on communication skills (outcome 6) and the wider social aspects of where these engineering solutions are implemented (outcome 7).

Interestingly, contextualised, socially based learning is not new. Lev Vygotsky's [14] central focus on learning was social, cultural, and historical, which form a complex system that one is part of. For Vygotsky, understanding learning, one must also look to the social processes from which a person's thinking is derived, while acknowledging the cognitive growth as a *collaborative* process as we learn through social interactions. It seems plausible to assume that if Vygotsky's points for learning were broadly incorporated in the universities embracing the social domains and allowing for multiple epistemologies to flourish under the university umbrella, there would be no requirement for decolonisation in the first place.

The next challenge is how to achieve contextual learning in the classrooms.

1.4 Ground Level: Perspective shifts in the classroom

The goal in contextualised learning is to allow the students an opportunity to add their own background into the learning system, thus contextualising the content. Cybernetics provides some principles that can assist the lecturer in taking a contextual approach with the students. For example, cybernetics is concerned with circularity and mutual causality. Glanville stated [15, pp.168-169]:

> The Principle (or Law) of Mutual Reciprocity states that, if through drawing a distinction we are willing to give a certain quality to that we distinguish on one side of the distinction, we must also permit the possibility of the same quality being given to that which we distinguish on the other side of this distinction: If I distinguish myself from you and I consider I am intelligent, I must consider that you (which I distinguish from I) might also be intelligent…

This principle explains how qualities such as intelligence may be understood to belong to both participants in an interaction, shared *in the between* [15]. In the classroom context, if the actors[1] (teachers) are to think of themselves as having knowledge, so too must they allow the other actors (students) to also have the option of having knowledge, for the teacher alone with knowledge is meaningless, unless this knowledge is being acknowledged by the co-learners in the shared classroom. There needs to be compliance/cooperation between the relational elements, with neither side thinking they are in

control. Acknowledging that the students too have intelligence and are not just blank slates, is an important step. While the students are not yet specialists in the fields they study, they are specialists in the context of their lives, for they are the ones who are living it. Thus, if one is aiming to contextualise the curriculums and have these curriculums reflect the students' own epistemology to some extent, an enquiry of the students' way of knowing is essential. It is impractical to assert that the teachers must befriend their students to enable a closer relationship in understandings. This is fraught with ethical problems and I am sure most would not like this option of reduced personal boundaries. However, it is still possible to achieve a level of engagement that does not challenge the reasonable social gap in teacher learner groups. Conversation theory (CT) is a useful tool to engage the students in their learning, allowing for the contextualisation of knowledge to be introduced in the classroom. One technique is referred to as Teachback [17], [18]. In this method, after the teacher has presented to the learners the topics of the learning outcomes, the learner is invited to teach back his/her understanding of this material to the teacher and the classmates. When the learner teaches back their interpretation of the new concept/s, they are providing a glimpse into their world of understandings, but more importantly how they arrive at these understandings is a feature that the teacher can use to improve the learning process. During the Teachback, the teacher stresses the *how* of knowing. This implies that the learner tells of how they arrived at their understandings. By focussing on the *how* rather than the *what*, the student is invited to tell of their own story in how they understand the content in their own lives. The teacher hears the learner's ideas about the concepts and what meaning they have attached to this content. The role of the teacher is to then use the diverse contexts of the students to adjust the curriculum to the contexts of the learners, embracing the learner's contexts and every day aspects. Thus, the teacher becomes what I call a *Creative Contextualiser*: finding interesting ways of placing the important curriculum knowledge areas in the territory of the learner's backgrounds so they may integrate this new content and understand it in a personal way. For example, if the knowledge area is waves and resonance, topics that students find interesting can be used as the context. Music and audio equipment including speakers and room design are not traditional study areas, yet still fall under the engineering branch of acoustics. Many engineering students are interested in audio, including car audio, disco setups and so forth. Contextualising waves and resonance in a student chosen context of music equipment, for instance, addressing student's questions in terms of speaker placement etc. allows for the students to have a personal experience with the topic. This in turn results in meaningful learning and better memory retention. This also means that the teacher learns about the students in terms of their way of knowing, as well as their interests and goals. This is in keeping with Vygotsky's [14] ideas about social learning in a collaborative manner.

According to Pask [19, p.45], learning begins with each student's aims or outcomes, which means that the teacher needs to work with the students' goals. This also means a new form of responsibility is created. New questions arise from this way of thinking and acting: how does the teacher take responsibility in the class? How do the learner's show their responsibilities? How do you know learning is taking place, and so forth? The answer to these questions rests on the mutually agreed upon roles and responsibilities that emerge in the classroom.

1.5 Limitations

Probably the most challenging aspect of contextual approaches is that there is a perspective shift that the teacher would need to embrace. While there are many methods to achieve this, cybernetics is not an easy option as cybernetics is not a theory, it's a way of being [20]. Teaching cybernetics to people has its own challenges including the shift from objectivity to personal relational meaning generation [11]. This means that one cannot simply think in terms of cybernetics without acting in a corresponding manner [20]. A level of authenticity is required, which arrives once the observer not only thinks cybernetically, but also lives it now in keeping with what Aristotle called the sophia and phronesis of knowledge. Thus, for inclusivity and circularity to be present within the classroom context, the learners truly need to feel part of the system. The lecturer has to create a context for the students to be responsible co-authors in the system. Removing the hierarchy from the traditional teacher leaner roles is one example. Allowing the students to adjust the modules incorporating the learners' requests creates a more interesting class, but also increases the spontaneity, which also translates to the requirement of the teacher being good on their feet. For example, for each topic the learners can decide for themselves what aspects of the real world they would like to know; the teacher can steer the course in that direction still maintaining the course outcomes, while now increasing the learners' interest. The learners achieve a level of immediacy, which is advantageous through topics that are personally selected, but it does also rest on the creative abilities of the teacher.

Adopting a conversational method in the classroom such as the teachback may be challenging when the group size is large. Turn taking rules become important with large groups, including the additional time to manage the different inputs of the students. There are workarounds for such scenarios, including the pre work that the teacher can perform and place on the online university module's forum, where the students can have pre-knowledge and early discussion of their own selected topics for the class. One may postulate that the students will not take actively participate; however, when the learning becomes personal, the interest is heightened.

1.6 Conclusion

Mahmood Mamdani [2] noted that epistemological transformation is central in the decolonisation of knowledge in South African universities. A cybernetic approach was

presented as one method of achieving the epistemological shifts in the university. The Greek word *Kybernetes* which translated into English is *pilot* or *steersman,* illustrates the role of the teacher in the new face of proudly South African Universities. The steering of the curriculum content into the diverse contexts that the students brings forth can allow for the contextualisation of knowledge, and thus the growth in a South African knowledge that has local meaning and benefit. Teachers will thus need to move away from linear thinking, now embracing a circular view of how learning is taking place in the class. A new role of the teacher as a steersman or a variety regulator is required, aiming to achieve sufficient variety to address the diverse inputs of the students. Having the variety or range of conversations and knowledge allows for a wider catchment of topics that can be positioned or framed in the hope that the students in the class will gladly accept and absorb this information into their own knowledge, thus not violating Ashby's law of requisite variety, which is that only variety can match, absorb or destroy variety [21].

The classrooms or conversation spaces should not be assumed to be always harmonious. On the contrary, the differences that arise in conversation is in fact the reason for the need to converse [22]. As the differences arise in conversations, so too will there will be conflicting ideas. It is through resolving these conflicts in the classroom whereby understanding can take place instead of rote learning, for learner and teacher are in conversation with one another. Without the conflict there would not be the opportunity for cooperation, which is one of the behaviours the teacher requires for there to be learning taking place. Notwithstanding that the teacher may also be learning from the information they receive from the students – each perturbing each other in a circular manner.

The students want to learn the content to achieve their goals, to which the teacher is the specialist in. However, the students are the context, thus the teacher is no longer the expert in contextualisation of the knowledge. The *map* is not the territory, as Alfred korzypski [23] and later Bateson reminded us. A map of something is not that thing without the human experience of the thing which one seeks to understand. To make the map the territory, one needs to place oneself in the content and context. Every teacher knows that it is much easier to present information to people when the audience can relate to the information, rather than relying on an abstract view of it. Achieving successful contextual teaching and learning will address the ideals set out by the South African Department of Higher Education, who specifically require that learning environments are constructed taking into account the contexts of the students, allowing for many methods for learning programs [1, p.48]. In simple terms, Viktor Frankl [24] reminds us that with increased freedom, comes increased responsibilities. Thus, as the students achieve more independence in their learning, they too will experience more responsibilities. But Frankl also reminds humanity in his book *Man's Search for Meaning* that in the face of serious extenuating circumstances, amazing achievements can be made when there is personal meaning attached to the situation. Teachers simply need to find the student's reason for being in the class and work with it. The road becomes less rocky.

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Conceptual Framework for Enhancing Engineering Education in Ghana's Polytechnics

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Abstract
Successive Governments in Ghana since the pre-independence era have all underscored the significance of engineering education as a catalyst for transforming and growing the economy as well as promoting national development. Polytechnic education in Ghana is also perceived as the panacea to the growing unemployment rate in the country and trains middle-level skilled manpower for industry for national development. However, Polytechnics have failed to harness its potential to enhance engineering education to meet the needs of industry in Ghana. Conceptualising factors that may contribute to enhancing engineering education in Ghana's polytechnic education in the face of the conversion into technical university is the focus of this paper. A brief review of Polytechnic education in Ghana from second cycle level to a technical university status is done. The study adopted the desk review approach by examining literature from journal articles, the internet sources, conference proceedings, books and other relevant materials related to the study. Five (5) critical factors have been discussed to have an influence on engineering education in Polytechnics in Ghana. These factors include competence-based teaching and learning, monitored industrial training/internship, funding, educational field visits and industrial collaboration. These factors if considered and implemented may enhance the quality of teaching and learning and translate in the quality of graduates churn out and above all improve the country's economic productivity.

Keywords: Engineering Education, Polytechnics, conceptual framework, technical and vocational education training (TVET), Technical University, Ghana

1. POLYTECHNICS EDUCATION IN GHANA

Polytechnic education in Ghana is perceived as the panacea to the growing need for middle-level manpower for industry and national development [1]. The need for employable high skilled middle-level manpower, therefore, saw the upgrade of the second cycle technical institutions to tertiary institutions in 1992 following the promulgation of the Polytechnics Law; Provisional National Defence Council (PNDC) Law 321 of 1992 [2]. This Law has since 2007 been replaced by the Polytechnics Law (Act 745) [3] which gives a clear mandate to the Polytechnics when it states their aims and objectives as:

- Providing tertiary education in the fields of manufacturing, commerce, science, technology, applied arts and applied social sciences,
- Provide opportunities for skills development, applied research and publication of research findings.

The mandate clearly indicates the central focus of Polytechnic education as career-oriented in nature. However, rather than it being a strength, this career-oriented focus of Polytechnic education has been primarily responsible for several agitations of both staff and students in the past. [2] and [4]

Undoubtedly, Polytechnics education has not been able to meet adequately this mandate expected of it by industry due to several challenges [1]. However, in the midst of all these challenges by Polytechnics to enhance engineering education, the president of the Republic of Ghana, His Excellency President ohn Dramani Mahama in his 2013 [5] state of the nation's address endorsed the National Council for Tertiary Educations (NCTE) organised forum's proposal for conversion of Polytechnics to Technical Universities (TU) earlier in 2012 [6]. The announcement in 2013 was given more impetus when H.E. President John Dramani Mahama [7] reiterated the government's commitment to convert Polytechnics into technical universities (TU) before September 2016 during the 2016 state of the nation's address before members of the Ghanaian Parliament. Students in the technical university are expected to acquire high-level technical skills to drive the country's economic and national development agenda [8]. The proposed technical universities have the potential of transmuting and growing the economy as well as promoting national development [9]. Technical Universities are supposed to contribute to improving the quality and competitiveness of the Ghanaian workforce and to provide top-up degrees for Polytechnic HND graduates. The various top-up programs (BTech and MTech) which hitherto was provided by the traditional universities, provided both theoretical and practical course of study leading to the award of a Bachelor of Science degrees (BSc); this form of further study gave Polytechnic graduates a different focus from practical hands-on training. TU will provide opportunities for companies and employees to upgrade and acquire new skills as well as exchange research and technology with industry [6]. The conversion seeks to empower the proposed technical universities with a different orientation from the traditional universities with high institutional and programme differentiation and diversification [6] and afford Polytechnic HND graduates higher qualification in the area of engineering education.

The assessment of the Polytechnics for conversion to technical university brought about a criterion for Polytechnics to comply. The criterion was to ascertain the

strength and preparedness of Polytechnics for the conversion. These benchmarks included the number of faculties and department in each faculty with an emphasis on the technical departments, the number of accredited bachelor of technology programs being offered by the Polytechnics. The academic and professional qualification as well as relevant industry experience of academic staff was critical for consideration. Industry collaboration, relevance industrial internship, physical infrastructure and finally staff participation in institution-industry collaboration were considered [9].

Whereas the conversion has been characterised by many critics including the minority members in Ghana's Parliament and Prof. Ayittey [10]; the Vice Chancellor of the University of Ghana as been hasty undertaking and done to serve the interest of few, Polytechnics community and stakeholders are keenly waiting for the conversion with high commitment to embrace this new challenge in the face of the many problems.

> "We know it will go wrong but why are we doing it; we are doing it because it will make a few people happy," the UG Vice Chancellor stated at a forum in Accra" [10].

To further enhance engineering education in the country and to reap the potential benefit it seeks to contribute to the national economy, there is the need for Polytechnics to position themselves strategically for this task. It is, therefore, imperative for Polytechnics to consider some critical factors and strive to uphold them high and work with it as a reference for enhancing engineering education in Polytechnics in Ghana, hence this study

2. ENGINEERING EDUCATION IN POLYTECHNIC IN GHANA.

Hitherto, engineering education in Ghana has been the preserve of the national universities with the focus on applied engineering [11]. Ghana has ten (10) National Polytechnics in the country with one Polytechnic each in the ten administrative regions in Ghana. These Polytechnics run various engineering programs at the non-tertiary, higher national diploma (HND) and bachelor's (Bachelor of Technology) levels in Ghana. Courses offered include automobile, civil, electrical and electronic, materials, ecological, mechanical, chemical, telecommunication and renewable energy systems engineering. Throughout the period of educational reform, several factors have potentially influencing engineering education in Ghana. However, these factors have not been critically looked at for consideration by Polytechnics as growth measures towards enhancing technical and engineering education in Ghana with a focus on skill development, and as a result, not all Polytechnics may qualify to be converted into a technical university to offer higher qualification degrees in engineering education. These factors identified through literature are discussed below.

2.1 Competence-based teaching and learning (CBTL)

Competence-based teaching and learning (CBTL) according to Adimado, et al. [6] and Agodzo, S.K [12], involves "self-direction enquiry" and or "do-it-yourself" (DIY) approach to learning which will translate to the development of skills. CBTL is regarded as the best form of training for Technical and Vocational education in polytechnics [13]. Rev. Prof Daniel Nyarko [14] argues that the success of every competency based training program depends on new approaches to curriculum and teaching material development, recognition of academic staff, purposeful staff recruitment and development, equipping training workshops with tools and finally instituting a framework for quality assurance. Ghana's Polytechnic engineering education has become bookish as posited by Idrisu, [1], instead of practical orientation. Afeti, [15] indicated that the curriculum for Polytechnics had been wholly adopted from foreign models without consideration for local needs. A few Polytechnics have however adopted this competency-based teaching and learning approach for some engineering program of study whiles others are yet to embrace the approach as a result of several constraints. Idrisu [1] posits that until recent, high staff turnover, unstable academic environment and curriculum delivery has been the main challenges in Ghana's Polytechnics. It is also the view of many that qualification indicating that graduates are either ***competent*** or ***not competent*** is not encouraging and motivating enough as compared with qualification indicating ***first class*** and ***second class*** as the case for other non-engineering programs. There is a lack of consistency and comprehensive curriculum for all Polytechnic which have resulted in different level of competencies of Polytechnic graduates for some industry in Ghana. Effah, [16] confirms the inconsistency of Ghana's Polytechnic education curriculum with UNESCO and ILO established criteria for providing core competencies needed for career development.

2.2 Monitored industrial training/internship

Industrial Training refers to work experience undertaken in the course of the program of study that is relevant to the professional development of students before graduating from the program. The importance of industrial/internship training towards engineering education is enormous both for the trainee, the institution (Polytechnic) and industry [17; 18]. In the current curriculum of Polytechnics in Ghana, industrial training is seen as a critical component of the teaching and learning process (It is a requirement for graduation) even though grades obtained in industrial training are not included in the overall cumulative grade point average (CGPA) of students. A well-structured and monitored internship training seeks to develop the practical and communication skills/competencies of trainees and strengthen industrial/institution in partnership [17]. It also provides a nationwide mechanism to address critical skill demand for national development as well as preparing students for real industry work through practical knowledge and hands-on training. Skill needs of the economy are readily identified [19] and filled in through curriculum development/modification. Finally, the development of trainees' personality and collaborative group work culture in work situations are enhanced. Patki Veena and Manasi Patki [19] further posits that from the hands-on training, required skill and demands of the industry, as well as work ethics, are learnt by the students. At the same time, it gives the student an opportunity to practicalize theories.

Upon completion of the industrial /internship training, a prescribed and final performance assessment is expected to be carried out both by the polytechnic institution and industrial training centre. The assessment will ultimately

help in shaping the curriculum to meet the particular needs of industry and equip trainees for real work situations. However, countless challenges befall this great idea as a result of few industries with limited spaces to absorbed trainees [1]. The non-availability of training centres within the jurisdiction of the training institutions and where most of the student come from has forced students to enrol on internship / industrial training in other regions of the country forcing supervisors to travel across the length and breadth of the country for monitoring and evaluation. Due to lack of financial resources for monitoring and evaluation, a non-supervised student who indeed may not have undertaken the internship can produce reports for evaluation which ultimately influences teaching and learning.

2.3 Funding

Funding is critical in the educational development of Ghana's Polytechnics in the face of the conversion to technical university status particularly in the field of engineering where sophisticated equipment and tools are required for effective teaching and learning. Funding for tertiary education in Ghana (both Polytechnics and universities) has been the Ghana Education Trust Fund (GETFund) and the Teaching and Learning Innovative Fund (TALIF) which is inadequate. Undoubtedly, most polytechnics lack essential tools and equipment for laboratories and workshops as a result of the inadequate funding of Polytechnics [20] which has significantly affected the output of teaching and learning at the various Polytechnics over the years. Some Polytechnics were disqualified for the conversion to technical university status as a result of poor infrastructure. Literature has it that Polytechnic education in Ghana has received relatively lower funding [10]. Rev Danial Nyarko [10] lamented on the poor funding of Polytechnics during the conversion to tertiary status. He reported that, Governments expenditures for Polytechnic students as compared to the university students stood at US$168, US$74 and US$1,000 for Polytechnic students as compared to US$2,100, US$900 and US$2,500 for university students for the years 1990, 1998 and 2005 respectively. Improved funding will obviously enhance research activities to improve teaching and learning to meet the immerging trends in engineering fields and the demand from industry. Applied research which is a core mandate of Polytechnics will be enhanced with improved funding [20]. Indeed, funding from central government for Polytechnics education can never be adequate since other sectors of the economy equally rely on financing from the same pool of central government funds. It is, therefore, important for Polytechnics to develop strategies to improve their internally generated funds (IGF) to ameliorate their budgetary allocation from central government.

2.4 Educational field visits

Educational field visit is events organised as part of the teaching and learning process to complements the classroom instruction by bridging the gap of practical experience. It is a vital part of teaching and learning. No institution, particularly in the case of Polytechnics in Ghana have all the tools, equipment's, laboratories and methodologies to demonstrate what is needed to be taught, in that vein, students are given the opportunity to have first-hand information regarding the functioning of industry and to have a feel of their future place of work. Studies by Gretzel et al., [21]; Wong and Wong, [22]; Sanders and Armstrong, [23] have underscored the relevance of industrial field trips in enhancing students' learning and increasing their practical knowledge in the absence of actual work experience. According to Sanroman, Pazos and Longo [24], cited in Sen [25], industrial visits give students understanding into their future professions by opening up opportunities to observe industrial processes in operation. Also, industrial visits benefit stakeholders by bringing them into contact with prospective employees. Various professional bodies for engineering education must endeavour to ensure Polytechnics comply with criteria for accrediting engineering programs at the Polytechnics. Given the importance of industrial field visit to engineering education, it is recommended that industrial field visits be made a curriculum requirement in Ghana's Polytechnic.

2.5 Industrial collaboration

Collaboration is a working practice or relationship where individual, stakeholders and partners work together to achieve a common purpose. It has been asserted by Bukaliya [18] of the existence of a gap between the quality of graduates and the real need of industry. In spite of the strong evidence of industry collaboration in most Polytechnics in Ghana as reported by Adimado, A.A *et al.* [6], it is, however, not reflective in its curriculum for teaching and learning. Industry influence is paramount in engineering education and as such must be harnessed to guide curriculum design and development, training and skill development, basic and applied research technology development and transfer [26] through seminars, workshops, practical demonstrations, etc. this will ensure course contents are tailored to solve industry needs. Collaboration between industry and Polytechnic will provide the platform for accelerated national development through research.

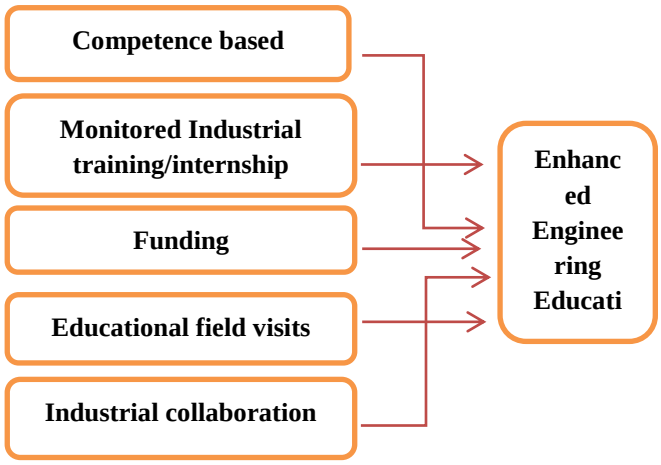

Fig 1: A conceptual framework for enhancing effective engineering education in Ghana

Conclusion/Recommendation

In conclusion, engineering education has the capacity to improve the unemployment rate of the country through hands-on manpower training to aide graduates to set up their own businesses without reliance on central government for employment. To achieve this, the study discussed five (5) factors that may contribute to enhancing engineering education in Ghana's polytechnic education. The factors included competence-based teaching and learning, monitored industrial training/internship, funding, educational field visits and industrial collaboration.

The study further recommends the following for implementation by the various stakeholder's (government, industry, Polytechnics) to guarantee enhanced quality engineering education.

- There is the need for a comprehensive curriculum design which is influenced by industry and adoption of competency-based teaching and learning approach for all Polytechnics in the area of engineering education to train students with the opportunity for individual Polytechnics to include specific and relevant subjects peculiar to the Polytechnics location.
- The government should adequately resource the Polytechnics financially in the face of the conversion into technical universities.
- The need to establish an industrial training fund cannot be overemphasised to ensure that financial support is available for monitoring and evaluating students on internship and industrial training.
- It is important for Polytechnics to develop strategies to improve their internally generated funds (IGF) to ameliorate their budgetary allocation from central government.
- A comprehensive database of industries within the jurisdiction of the Polytechnic is necessary to facilitate placement of students for internship/industrial training.
- Given the importance of industrial field visit to engineering education, the study recommends that industrial field visits become a curriculum requirement in Ghana's Polytechnic.
- The National Accreditation Board (NAB) must ensure that any Polytechnic seeking accreditation to run engineering programs has the said department or program affiliated /accredited by the appropriate professional body within the country such as the Ghana Institution of Engineers.

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Innovating Engineering Education to Foster Soft-Skills: Challenges and Opportunities

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***Abstract* - Globalisation and technological advancements have flattened engineering practice. Not only that, the emergent global challenges and the rapidly evolving technologies are changing the role of engineers in society. It is no longer sufficient for an engineer to master only a scientific and technological discipline because employers are looking for graduates who have both, a sound educational background as well as 'soft-skills'. Thus, today's engineers need to transform from technical problem-solvers to more cooperative creators. But the problem is that: most engineering programmes still focus on "hard" technical skills and the didactic lecture methods adopted broadly by engineering faculty is said to be ineffective as it does not foster active learning. The challenge therefore is finding ways of integrating soft-skills into engineering education as well as assessing them (soft-skills). We attempt to fill this gap by exploring the vast body of research on soft-skills and review some of the innovative pedagogical strategies that foster such skills. We equally explore some innovative assessment techniques relevant for 21st century skills. This paper joins the call that innovative evidence-based educational strategies be institutionalised and disseminated.**

***Keywords* - Soft-skills; 21st century skills; graduate attributes; engineering education; engineering challenges; problem solving skills; universities**

I. INTRODUCTION

The rapidly evolving technologies, especially information and communications technology (ICT) and globalisation have changed the role of scientists and engineers in society. Market internationalisations require engineers capable of working with and among different cultures and knowledgeable about global markets [1]. Today's world faces complex challenges from different fronts – business political, scientific, technological, health and environmental challenges [2], insecurity and terrorism, food security and poverty, etc. These complex problems will require sophisticated problem solving skills and innovative, complicated solutions [3]. Therefore, today's engineers need to transform from technical problem-solvers to more cooperative creators [4]. It demands broader skills and that in the future, it will not be enough for an engineer to master only a scientific and technological discipline [1]. Hence, the critical aim of those attributes (skills) is about meeting workforce needs, global economic competitiveness and the capacity for responding to global challenges [5].

There is the real problem on sourcing people with relevant soft-skills across the globe: as is prevalent in the United States, Mexico, India, China, Poland, etc. [6]. Recent studies indicate that newly hired graduates have not mastered certain higher-level skills known as '21st century skills' (soft-skills) at levels that employers expect and need [7]. Research on the soft-skills displayed by engineering graduates confirms that tertiary institutions are often sending out robots, not the human being we would like [6]. Thus, these changing roles necessitates responses from engineering education to address the non-technical requirements of engineers [8].

However, what remains uncertain is whether and how our universities are preparing today and future engineers for 21st century practice. Unfortunately, as observed by several researchers [1]; [6]; [7] science, technology, engineering and mathematics (STEM) education seems not to be equipping graduates with higher order thinking skills (HOTS) - innovativeness and creativity; literacy; informational skills; collaborative problem solving skills, etc. needed to address those challenges. This is no surprise, as established engineering programmes tend to educate students to be specialised and technical problem-solvers within their disciplines [9].

The question is: how do we integrate soft-skills into our engineering programmes, and how can these soft-skills be assessed? The didactic lecture methods adopted broadly by engineering lecturers is said to be ineffective and does not foster active learning. Conversely, some researchers claim the respite is with the adoption of innovative pedagogical strategies that enhance active learning practices in the classroom. This paper seeks to fill that gap. In a bid to achieve the above objective, we first review existing research to examine what is described to as soft-skills in the literature. We equally undertake a review of the way engineering courses are taught in our universities and examine some of those evidence-based educational innovations – collaborative/cooperative learning (CBL); experiential learning/learning-by-doing; problem- or challenged-based learning (PBL); etc. acclaimed to be fostering soft-skills.

II. SOFT-SKILLS OR NON-TECHNICAL SKILLS

While university engineering programmes often focus on "hard" technical skills, it is becoming increasingly evident that in order to compete in a global environment, international engineering students must become competent in certain

essential soft-skill [10]. The 21st century workplace is seeking graduates that can work in teams with people with diverse expertise [3]. Engineering businesses (companies) are now looking for engineers that possess both technical understanding (i.e. sound knowledge of disciplinary fundamentals) and enabling skills (soft-skills) [11]. The Academy considers soft-skills as a set of abilities that enable engineers to work effectively in the work place, by being able to apply theory in practice. According to [12], the Accreditation Board for Engineering and Technology (ABET), National Academy of Engineering (NAE) and the American Society of Engineering Education (ASEE) all stressed importance of non-technical skills for the engineers of the future. Again, recognising the fact that, the engineer is a human first, the Engineering Council of SA (ECSA) acknowledges the importance of soft-skills within the profession [6].

The so called essential skill sets now required of every graduates are referred to as: employability skills, graduate capabilities, graduate attributes, soft-skills, 21st century skills, generic skills, non-technical skills – contextual skills, etc. Fisher [13] maintains that, for engineers, graduate attributes or graduate competencies might be expanded to include critical thinking, communicating to peers and the wider community, working in multi-disciplinary teams and environmental literacy.

Fisher et al. [14] states that, the American professional engineering community has maintained a consistent need for professional, communicative, and innovative engineers in the workplace. The lists such skills as included in the ABET Engineering Criteria 2000 (EC2000) Criterion 3 Outcomes to include teamwork, ethics, communication, understanding of engineering impacts, passion for life-long learning, and knowledge of contemporary issues. Other are: sociotechnical competence, entrepreneurship, reflective thinking, global citizenship, cross-cultural competence, [4], [9], [12], [14] – [16].

III. CHALLENGES OF FOSTERING SOFT-SKILLS

A critical challenge lies in creating appropriate educational environments and instructional strategies that foster the development of employability skills [17]. But engineering curricular that are already-strained [12] with narrow and discipline focused programmes with heavy workloads [5] seem not to allow room for the introduction of other activities that would have led to a more effective learning experience for students. Again, most engineering programmes seem to be divided into two worlds on unequal footings, the technical and non-technical [8]. Indeed, traditional science training and engineering education typically focuses on providing graduates with technical knowledge and skills acquisition [3]; [5]; [8]; [10]. Closely related to the above is what [18] termed as "disciplinary egocentrism" which refers to students' lack of readiness to engage in multidisciplinary education, and the unwillingness of faculty to engage in alternative approaches to their discipline. They point to disciplinary egocentrism as the greatest challenge to embedding soft-skills in engineering students.

The dominant engineering pedagogies without any significant change over the last thousand years [19] has been the lecture method: "chalk and talk", lab experience and homework [18]; [20]. The authors claim, the above methods have suffered severe criticism because of demonstrable research evidence concerning their ineffectiveness. For example, [21] insist such didactic methods are limited by the fact that a gulf exists between specific learning outcomes and their relevance to social knowledge construction. They barely oriented students toward retention of facts and analytical skills [20], but neither foster problem-solving skills, nor may help in knowledge transfer, in promoting HOTS in students [18]; [21]. Consequently, some researchers argue, non-technical competencies are unlikely to be developed through traditional teaching methods [6]; [22], and such pedagogies may not prepare students for innovative and flexible role of engineers in today's society [1].

IV. OPPORTUNITIES FOR FOSTERING SOFT-SKILLS

The challenges of fostering soft-skills in engineering students can be met through non-traditional methods [22]. There are some pedagogical approaches to transforming educational practice that seem better suited for the job than others [23]. We can achieve this objective by adopting the right educational innovations. Educational innovation refers to any new instructional material, strategy, or pedagogical approach that differs from the current and previous materials or methods employed by an educator [24]. Wilson et al. [25] opine that non-core engineering courses including leadership and engineering management can help students develop highly desired attributes to career and industry success.

A. Innovative learning environments

Our current built learning environment infrastructure is not well suited for most innovative teaching and learning methods. These learning spaces need to adapt to meet the emerging needs of a wide range of pedagogies. Such environments are what Fisher refer to as technology-enabled active learning environments.

Technology is an indispensable component of any activity [26]. Educators need to constantly respond to a shifting educational context [27]. Dogan [26] explains further that technology may contribute to design and implementation of the STEM activities in various ways. It can be directly integrated and embedded into STEM activities or it can be used as tool or facilitator to enrich STEM teaching/learning. For example, [28] argues that the use of multimedia and other learning technologies have strong pedagogical advantages in stimulating greater student engagement because it enhances teaching and 180learning and complements traditional approaches to learning. Learners can use technology to find solutions to the problems in a creative and challenging manner, especially under project/problem-based learning environment. The use of technology would encourage

students to become innovative and develop their creative thinking while they work on their projects [26]. Therefore, in order for engineering faculty to be able to teach effectively in this 21st century, like what [29] said, teachers of the future, should be exposed to and gain mastery in many new and emerging technologies with potentials for instructional purposes.

B. Innovative pedagogies that infuse soft-skills

Takala and Korhonen-Yrjänheikki [15] are of the view that, quite obviously soft-skills cannot be achieved by simply adding new content to existing courses or creating new courses, but that they need to be integrated in all degree programmes, combined with the core technical competencies. This view is supported by [6] who argued that, teaching and learning strategies that infuse soft-skills have to be consciously taught to the engineer as they are not learned by diffusion, rather, scaffolding of teaching and learning has to take place across modules and across the programme. Litzinger et al. [30] also emphasised the need to incorporate elements of instructional practices that are likely to lead to learning that supports the development of expert professional practice. Some of the innovative pedagogical strategies are below:

Blended learnings: Advances in ICTs have provided remarkable opportunities for 21st century blended learning models – simultaneous online and face-to-face – and seriously called into question the industrial-age traditional "egg crate classroom" model of teaching and learning [13]. Blended learning is the seamless amalgamation of carefully selected online modules with face-to-face instruction [31], [32].

Collaborative/cooperative learning: Engineers are often required to apply critical judgment in solving their problems and this requires that they learn continuously as they practice [33]. In this method, students work together as a team to achieve specific target or objective [34]. CBL incorporates five specific tenets, which are individual accountability, mutual interdependence, face-to-face promotive interaction, appropriate practice of interpersonal skills, and regular self-assessment of team functioning [35]. It is claimed to foster deeper understanding of new concepts and ideas after having had the opportunities to talk and explain concepts to the other members of the group [36].

The "flipped classroom": The "flipped classroom" also called the "inverted learning environments" [19]; [37] has become one of the most talked about trends in education. It has universal application across different ages and disciplines. This pedagogical approach inverts the typical university style of lecture-based teaching by letting students view short video lectures at home before the class session [37]. In this model, the usual practice of spending class time engaged in direct instruction and completing content related activities for homework is "flipped", so that students receive initial content instruction at home, and spend class time working with their peers in a collaborative setting [38], [39]. That is, what used to be classwork (the lecture) is done at home via teacher-created videos and what used to be homework (assigned problems) is now done in class [40].

Narratives and storytelling: It sometimes joked that engineers are lousy communicators, because their education includes no training in fiction [41]. Admittedly, while teaching engineering majors direct communication can in many ways prepare them to do the writing tasks that they could encounter as engineers, it was not in itself inadequate, but that indirect communication in the form of literature has the potential to cover some of the inadequacies, producing a kind of literacy salient for engineers [42]. Most importantly, [9] [43]; claim, storytelling provides a vehicle for scholarly discourse that makes explicit, our implicit knowledge, promotes reflective practice, and provides entry points into a community of practice.

Problem-based learning: There is a great deal of research which has explored aspects of PBL as a teaching and pedagogical strategy that fosters soft-skills [26]; [44] - [48]. PBL is an active-learning, learner-centred instructional approach that provides students with opportunities to construct their own knowledge through peer interaction and collaborative inquiry [49]. The goal of PBL is to enhance students' ability to utilize different process skills such as the development of critical thinking or reasoning, high professional competency, knowledge acquisition, the ability to work productively as team members, by collaboratively solving complex real-world problems, and take decisions in unfamiliar situations [26]; 49]; [50].

Project-based learning: This approach is closely related to PBL learning and it is used interchangeably in some cases. However, PjBL based learning is an approach to learning that focuses on developing a product or the creation of an artefact of some form [18]. The approach tends to integrate subject knowledge into projects, empower students to direct their learning activities and overcome separation of knowledge and practice [46].

Peer led team learning: The PLTL approach involves students learning in study groups or in teams. Students tend to learn informally from one another when they either work and learn collaboratively [51] especially when the work in teams. Being novices, students speak the same language and so can play an essential teaching role in partnership with their instructors [52].

Inquiry-based learning: This method is reported to have been widely used in the sciences: biology, mathematics, physics, etc. [52] - [54]. Evidence reveals inquiry-based activities can boost students' learning in a wide range of school subjects [55]. IBL creatively combines the best approaches to instruction, including explicit instruction and small-group and guided learning, in an attempt to build on students' interests and ideas, ultimately moving students forward in their paths of intellectual curiosity and understanding [23]. Within the context of mathematics, Kogan et al [56] states that the IBL approach engages

students in exploring mathematical problems, proposing and testing conjectures, developing proofs or solutions, and explaining their ideas.

Experiential learning: Experience-based learning, work-based learning (WBL) or work-integrated learning (WIL), learning through participation (LTP), and service learning are all similar. They are all variants of Kolb's 1984 Experiential Learning Theory (ELT). Work-based learning strategies are designed to equip learners with not only knowledge, but also the practical skills and personal attributes of their professions [57]. Through deliberate practice at the work environment, students hone their expertise as they continue to build knowledge, skills and attributes. Work-based learning has evidently been successful in promoting employability and enterprising behaviours in the UK and elsewhere [58], [59].

V. CHALLENGES AND OPTIONS IN ASSESSMENT OF SOFT-SKILLS

The essence of testing is to reveal latent abilities of testees [60]. Likewise, the merit in assessment for whatever reason is measured in terms of its appropriateness (validity and reliability) and the quality assurance outcomes [61]. A candidate's ability to perform in an examination or test should be based only on what we produce as individuals using a repertoire of knowledge and skills that are responsive to particular task(s). However, as the teaching and learning processes are changing, so also are the assessment procedures, at least expectedly [62]. Thus, the question will be, whether or not conventional testing practices take care of the innovations (the so called pedagogies intended to infuse soft skills) within the school system. Some author claim that one of the most daunting challenges facing engineering educators is the assessment of the actual learning that takes place in a classroom environment [63]. This gives the impression that adding assessment of soft-skills to this bouquet might seem like adding pepper to an open wound, and so, it seems when we tackle the challenge of infusing soft skills into our STEM learners, another of assessing them arises.

Acceptability and universality of common assessment measures in nearly all educational systems is already an issue [64]. The conventional testing techniques are said to be no longer appropriate for testing the new skills (soft skills) [62], and soft-skills cannot be overtly measured [6]. Likewise, many traditional methods do not address or adequately measure the new kinds of learning that this type of education seeks to engender, such as the so-called soft-skills [65]. In fact, such assessments rarely examine how to foster scientists' creative, cross-disciplinary problem identification and solving skills [3].

Part of the problem according to Chew [62] is that schools lack dynamic systems that can help teachers pull information together for the purpose of testing or profiling student talents, abilities or problems in learning. But assessments for establishing the existing knowledge level of students is critical for guiding future curricular materials geared toward enhancing non-technical skills [12]. It therefore imperative to device more innovative and appropriate ways of assessing students in these new skills, using either new techniques or new ways to use old techniques of testing [62]. Thus, unlike the standardised testing techniques where it is difficult to tell whether students have the capacity to use wisely what knowledge they have acquired [64], these innovative assessment methodologies should really reveal the level of mastery of knowledge, skills and aptitudes presumably acquired. Technology will have to play a significant part in the assessment processes and some of the assessment methods are discussed below:

Technology enhanced assessment (TEA): TEA methods are assessment practices that make use of varying technologies, particularly ICTs to measure student achievements. Technology-enhanced items have the potential to provide improved measures of student knowledge, create more engaging assessment environments, and reduce the effects of guessing and test-taking skills [66]. CAA generally defined as the use of computers in assessment to assess students' progress have also been used to assess PBL outcomes [50] as well as in flipped classrooms [67].

E-portfolio is useful tool that enhances the assessment of experiential learning in engineering education through [68]. The e-portfolio assessment system was developed to facilitate the assessment of student work. This system includes a repository of student work, faculty assessment criteria, and course specific learning outcomes [69]. E-portfolios also referred to as digital portfolios or web folios are an electronic representation of one's work – a purposeful digital collection (called artefacts) [70]. Such artefacts showcase students best work, to demonstrate efforts, abilities, development, and to provide opportunities for reflection on their learning process and progress toward particular achievements or goals [49]; [70].

Rubric: it is a multi-purpose scoring guide for assessing student products and performances in addition to improving teaching, contributing to sound assessment by providing feedback to students, and are an important source of information for programme improvement [71].

Self and peer assessment: Research findings demonstrate that peer assessment does indeed foster the kind of student interaction on which STEM depends, namely, inter-peer discourse, observational skill sets, professional critique, and related skills that build critical thinking [72]. Since lecturers cannot assess certain aspects of active learning approaches directly, as s/he is not involved behind the scenes where student interact among themselves, peer assessment becomes a handy strategy to address this shortcoming, so that each team member can serve as a proxy assessor for the lecturer [73].

VI. CONCLUSION

The literature reveals that non-technical skills are as useful and needed, as are technical skills, if engineers must function well in this 21st century and beyond. Nevertheless, there are

the problems of how best to integrate soft-skills into engineering education and how such skills could be measured. Here, we tried provide answers through a review of the literature. Engineering education must foster the creation of a critical mass of individuals with greater creativity and HOTS. They should also know the needs of a rapidly changing society – the students need to be diverse and lifelong learners. This review of the evidence-based practices in education constitutes neither a systematic nor an exhaustive one. Not minding the claims of successes, both the pedagogical innovations and assessment methods have their pros and cons. It is the responsibility of engineering faculty to adopt and adapt the options best suitable for a given circumstance.

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Preparation of Internationally Recognised Professional Engineers: A procedure for Designing a Sustainable Engineering Curriculum with a Focus on Africa

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Abstract **- This paper outlines an ongoing doctoral research project, at Curtin University in Australia, that seeks a solution to the lack of appropriate and sustainable curriculum design for Engineering Education with a focus on Africa. The proposed research title is "Preparation of Internationally Recognized Professional Engineers". The main objective is to develop a systematic procedure for designing a curriculum, aligned with methods of teaching and learning, to develop an engineer who can effectively contribute to the global engineering community. It combines the systematic problem solving concepts from engineering design with backward curriculum design concepts to create a curriculum design procedure that will take into consideration the local context in which the curriculum will be delivered. A critical review of existing literature has been done with the focus on Africa. Issues of internationalization of engineers will be explored as initial themes for data collection and analysis. Case study qualitative inquiry is employed on a selected case of Tanzania. This paper further explains the framework, significance and likely outcomes of the PhD study.**

Keywords **- International Engineer; Sustainable; curriculum design; Engineering Education**

I. INTRODUCTION

Globalisation and revolution in information technology in the 21st century has pushed the need for engineering education all over the world to produce international engineers who have attributes and skills that will enable them to practice and be recognised anywhere around the world. In the changing world Engineering is becoming more complicated; with the current job market being multicultural, multidisclipinary and of changing environments, therefore demanding engineers with broad skills beyond their technical abilities [1, 2]. This demand has implications on engineering education institutions around the world to develop this 21st century engineer. Research on engineering education [3-6] have addressed increasing opportunities, challenges and mobility of engineers around the world and have stressed need for transformation in engineering education.

There are emerging discussions in Africa, including those of the 5th African Conference Regional Conference in Engineering Education by African Engineering Education Association (AEEA), about the challenges and opportunities of the engineering education and the skills and attributes that the African engineer of the 21st century require in order to solve problems of the changing world [2, 7-9]. In the conference, Funso Falade[7], the president of African Engineering Education Association, highlighted the challenges of engineering education in Africa; poor funding, inadequate facilities and human capacity, brain drain, traditional teaching approach. Falade [7] established that the existing curriculum does not contain the local context, is said to be too academic and it does not provide adequate humanities, social sciences, business management concepts and entrepreneurship skills development. The conference advocates the review of curricula in engineering education among other things [7]. One presentation [8] recommended 5 things that engineering education has to adopt in order to develop the locally, globally competent engineer which include curriculum innovation, learner focus, accreditation, industry –university partnerships and education of the educators.

This paper presents a PhD study at Curtin University with the main objective, to develop a systematic procedure to design a curriculum and methods of teaching and learning to develop an internationally recognized professional engineer, with a focus on Africa. Through literature review, the research established a need for a systematic approach that can be applicable internationally, to develop professional engineers who will meet international professional engineering standards. It also identifies the marginalisation of Africa in the international efforts towards developing the 21st century engineer which is referred to as an internationalised engineer in this study. The research takes into consideration the local context in designing of appropriate curriculum for development of engineers in this case the African context.

II. Literature Review

A. Developing Skills for the International Engineers

A Professional engineer has been defined in Hoover and Fish [10] as "a person *qualified* by *aptitude* and education to *solve engineering problems* and to direct engineering activities." Because of the changes in the profession Engineers now needs to have a greater breath of capability coupled with specialized technical competence than that required of a previous generation[11]. A professional engineer from [10], Sheppard, et al. [12], [13] should be someone who is able to integrate problem solving and knowledge towards some meaningful end.

Patil and Codner [3], [6] have stressed the importance of global skills for this century. Spinks, et al. [14]concluded that firms are looking for engineers who combine technical expertise, strong interpersonal skills, and an awareness of commercial realities skills. From literature [3, 11, 14-17] it can be summarized that the generic skills and attributes required of a the 21st century engineer include: Knowledge of Engineering and Sciences, Problem solving skills, Interpersonal and Communication skills, Teamwork and Individual Skills, Ethics and Social Responsibility, Environment and Sustainability, Commercial awareness, Multicultural skills, Ability to work in diverse society, Project Management and Finance.

Literature reveals an existence of substantive discussion and activities that suggest internationalisation of engineering education and accreditation as the preferred approach for developing a global engineer around the world [6, 18-23]. Most have suggested that internationalisation of accreditation systems will harmonize engineering curriculum as well as the engineers' standards around the world [20]. There are also initiatives that have been successful in ensuring the competencies are developed implemented such as the CDIO and Tuning [24, 25]. There is a need to assess the applicability of the proposed methods/models globally to develop global engineers. There has been an increasing inclusion of the African perspective in many of the internationalisation efforts and discussions, and some literature is beginning to emerge from Africa [26-28]. As part of this PhD, the methods will assess the African context from the African perspective so as to get a deeper understanding of the local issues in engineering education and their causes.

To ensure the global applicability of the developed procedure in this research, the study identified the need to explore the local context to which a particular curriculum and teaching and learning will be applied in this case the African engineering education environment. There is a need to establish the current situation in the curriculum, teaching and learning and assessment and also the factors associated to the current situation. Therefore to begin, a critical review of existing engineering education and accreditation was done in order to establish the issues that are related to Africa.

B. Review: 'Internationalization of Engineers: a challenge for Engineering Educators from an African perspective'

A review of current research in internationalisation of engineering education and accreditation, with particular focus on global applicability was conducted with justification of the need for an international collaboration in transforming engineering education. The review highlights concerns about the marginalization of African countries in global efforts and aims at representing African issues alongside general issues. The existing systems of international accreditation and reciprocity agreements are critically reviewed and concerns for internationalisation are discussed. Published issues of internationalisation and accreditation in Higher Education in Africa are assessed. This review establishes the current situation of engineering education together with the challenges and opportunities and hence an understanding of the African context.

This review has generated initial themes that will guide data collection and analysis. The review has also resulted in a Paper that has been submitted to a journal for publication. The themes that have emerged are:

- Accreditation is one mechanism for African countries to enhance recognition and establish competencies of graduates. However, to maintain sustainable ongoing international accreditation participation many challenges must be overcome such as cultural, political and economic contexts.
- Engineering education in Africa needs to transform from a traditional delivery to a student centred and active delivery. This transformation in teaching aligns with international initiatives with an emphasis on developing competencies in contrast to the syllabus driven curriculum design and teaching styles.
- The transformation of engineering education would necessitate and initiate a transformation of education culture with an emphasis on teaching quality, innovation and scholarship of teaching and learning.
- An accreditation system within Africa or engaging Africa within a global accreditation system would require a system that was cost effective, industry engaged, transparent and self-funded in order to be sustainable. This may require a financial and/or institutional reform to secure funding and independence.

III. The Research Methodology

A. Education Process Framework

The main aim of the PhD research is developing a systematic procedure to design a curriculum and methods of teaching and learning to develop an internationally recognised professional engineer. In order to achieve this aim, it is useful to consider the progression through which a professional engineer is developed. The progression can be considered at as a cycle of input, process and output (IPO) as illustrated in Figure 1 derived from Patil and Gray [20]. The research will approach curriculum design and teaching and learning via a backwards curriculum design method, that is, by considering the competencies required of an international engineer to create the engineering education process to help develop those competencies. The boundary of the process can be defined as the local context which incorporates the pre-tertiary education of students, the tertiary education and the engineering environment in which they will emerge as graduates. An important aspect of the process is the feedback

loop. The feedback is derived from the engineering industry, graduates/alumni, academia, and professional or regulatory bodies.

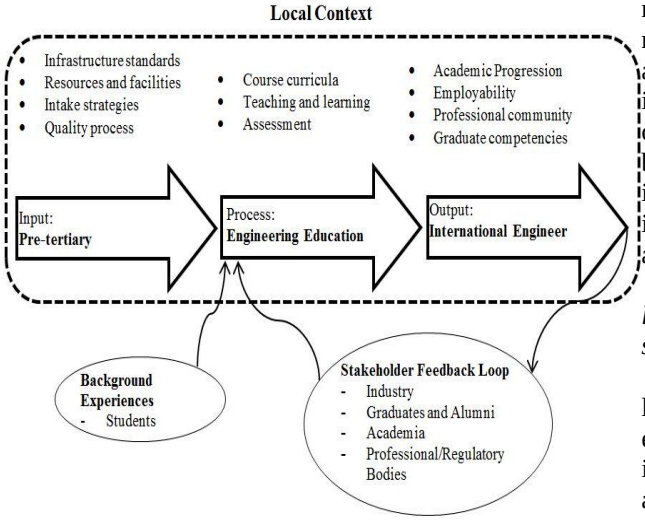

Fig. 1. The Higher EducationProcess as modified from Patil and Gray [19, p. 15]

By considering this feedback, the institution can incorporate continual improvement processes to enhance the process of engineering education. This process necessarily includes course curricula design, teaching and learning and assessment of capabilities and attributes of engineering students. The influence of the pre tertiary education is also included in the IPO process; the institution must take into consideration the background experiences of the student especially in relation to prior teaching and learning style, exposure to resources and standards, and the quality and preparedness of student intake. These influences are summarized in Figure 1.

The research focuses on the engineering education process and international engineer competencies. Engineering education (at a tertiary level) is the first and basic level of development of engineers, since it is recognized that engineers develop competencies through engagement with engineering work post-graduation (called Stage 2 competency, for instance, in the Australian context). The post-graduation development of competencies is outside the scope of this research and the IPO process as defined by Patil and Gray [20], used to frame this research.

B. Research Objectives and Data

The research objectives are:

1) To establish accepted definitions and competencies of internationally recognised professional engineer.

The information required for this objective includes accepted definitions, skills and attributes of a professional engineer as given or required by various instituitons, countries and engineering professional bodies. The source of this information will be Journals papers, books, government and professional bodies' websites, industry and professional bodies officials. The purpose of this is to gain a definition of a professional engineers' competencies based on historical evidence and current understanding.

2) Assessing engineering engineering program accreditation systems

To achive this objective the research will include an analysis of engineering accreditation systems. There exist a number of accreditation systems in the world and this research will establish their strengths, weaknesses, aims, achievements and the standards they set. The source of such information will be journal papers, conference proceedings, official websites of engineering associations, professional bodies officials and anybody with authority to give their view in this topic. The outcomes of this objective will be identification fo the existing accrediation systems' strenghts and weaknesses and their applicabitliy to the African context.

3) To identify the range of pretertiary and tertiary learning experiences and opportunities of engineering students in Africa

The issues such as student's cultures, backgrounds, learning environment, accessibility to education, socio – economic situation in the african context is addressed. This information can be found in published literature (journals articles, conference papers, books and so on), official website of governments and NGOS, and from graduates and alumni. This objective will produce an understanding of the background and learning experiences of students in Africa and how this may influence the engineering education process.

4) To propose a procedure for designing an appropriate curriculum structure and essential learning environment for engineering degrees suitable for international recognition.

The analysis of information collected in objectives 1, 2 and 3 will result in a list of specific criteria for designing a curriculum used to achieve objective 4. The approach is to backward pass of the Education IPO process (from output to process approach). Additional information required for objective 4 will be the curriculum, its contents and methods of delivery and learning outcomes including results, reports and performance statistics. The source of this type of information will be the academic institutions that are selected for investigation.

C. Case study Methodology

This study aligns itself with previous and current studies in Engineering Education by adopting a qualitative methodology [29]. Qualitative methodologies have been advocated by other engineering researchers to better address challenges in engineering education like innovative pedagogies, diversity and the changing requirements for engineering graduates in the twenty first century[30, 31]. The data analysis will use inductive approach [32] meaning that there were no preconceptions or identified hypothesis which is driving the research but rather perceptions and findings for this research are expected to emerge throughout the study [31]. The research will focus on smaller samples in order to examine the contexts in great detail and to describe the situations in enough depth. The sample selection will also be purposeful, particular samples will be selected because of their unique experiences or individual situations to provide important insights [31].

Case study methodology was selected for this research mainly because of its ability to answer "how" and "why"

questions which are dominant in the research. It will make use of case study inquiry to examine the context in great detail in order to generate the full meaning which can later be transferred to other situations [31, 32]. Tanzania is selected as a case study in order to provide an in-depth study of the established themes in order to develop a procedure to be adopted in any other African country to develop engineering curriculum for training international engineers. Further, case study methodology is best to use because of its ability to work with multiple data[30, 33] gathered from three different sources such as the case in this research; documentary evidence, archival evidence, interviews and focus groups.

D. Data Collection Methods

1) Documentary evidence

This research aims to take advantage of information available in documents and the relevant rich literature around the topic such as documents from official websites of accreditation systems. This information can be found in published literature (journals articles, conference papers, reports, books and so on), Official website of governments and archival documents. Documentary method of data collection has been endorsed to be important in educational research, because of the valuable information contained in documentary evidence [34]. Documents and archives are commended for their richness in information, their relevance and effect in the world, for being naturally occurring and independent of the researcher's inquiry. In addition to that they are readily available and accessible and would mostly likely not require any ethical considerations [35]. The research uses information available, institutional, governmental or publicly.

2) Interviews and Focus groups

To fill a perceived gap in literature on some areas especially on identifying the national skills demands for engineers, interviews of elites from the industry and focus groups of alumni are conducted. Focus groups and interviews are also used in academia to collect information regarding curriculum and delivery from engineers' educators and engineering education researchers. Semi structured questions will be used in order to allow views to raise from the discussions in order to gain a better understanding of the skills in the local perspective. Focus groups will also be used to obtain the initial overview, perspectives of the system of education responsible for development of those skills from groups such as alumni, academics. Interviews will be used to gain views of the elites such as engineering industry experts, deans of institutions, curriculum developers and professional and accreditation bodies' officials. A case study protocol [33] is used to guide the research with question guides for interviews and focus groups and to ensure reliability of the data collected.

E. Data Analysis

The unit of analysis is the Input- Process- Output educational process in engineering education focusing on Accreditation, Curriculum design and methods of teaching and learning. The first three objectives of this research follow the Input-Process-Output (IPO) starting by establishing the required output, then identifying the input and the existing process then developing the appropriate education process for training engineers that will consider the input students learning experience. The form of data from different IPO stages may vary depending on the source from which it can be accessed.

All data in form of text are organised and analysed using Nvivo10 software, a powerful qualitative analysis tool. This means that interviews and focus groups discussions are recorded and transcribed into text. Different forms of data (Interview, focus groups, documentary evidence) are analysed separately using thematic analysis technique. Thematic analysis involves three main stages; data coding, condensing and interpreting as clearly stipulated in chapter 9 of Kvale's book on Doing interviews [36]. For documentary evidence, the research takes a problem oriented approach to analysis whereby themes are established from the secondary literature before going to the documentary information which is the Primary data [37]

Intrepretation of data starts as soon as data is availavle and is carried out through out the research [35, 36] to allow for new themes to emerge and old themes to be confirmed. Critical intrerpretation of data is done by the researcher explaining meanings underlaying the participants view, that means going beyond what is in the text (documents and transcripts) [35, 36]. The discusion of data is done with the use theory to show contextual sensitivity and to ensure quality of results [35].

F. Ethics issues

Ethical approval for the research with low risk was obtained from the Curtin University's Human Research Ethics Committee (HREC) for this research. This lower level human research ethics does not involve any likely vulnerable groups such as children and youth under 18 years of age. The participants aimed for in this research are all above 18 years of age. However care will be taken at every step to ensure protection of participants and to avoid any potential ethical issues such as those that could occur in focus groups due to heated debates [38]. To avoid this participants are provided with information sheet to explain the topic of the focus group and they have to sign consent forms before participation. There is also debriefing before every discussion and participants are provided with researchers contacts should they have any concern afterwards. Participants are allowed to cancel their participation or decline for their data to be used any time before publications. Participants identities are not disclosed unless on their consent if there is a need due to their authority for credibility of the data.

G. Limitations of the study

Practical considerations that have affected my choice of methodology include time, fund, and access to data. Time limitations include time to complete the doctoral research and time available for data collection - the amount of data that can be collected depends on the time available[34]. Funding limitations considers the fact that this research began as self-funded, not under any scholarship. The methods selected will depend on how much the researcher is able to access including making good use of connections that the researcher and supervisors have established in the areas that need to be researched. Although time and funds are limited, care is taken to ensure that quality of the findings (reliability and validity)

is not compromised. Triangulation using more than one data collection method to crosscheck the findings [34].

H. Initial Study

An initial study was conducted in Tanzania during the researchers visit for the purpose of testing the data collection tool and further shape the data collection protocol. The study included three interviews of elites in engineering academics and industry and one focus group of engineers who are alumni from a University in Tanzania. The analysis of the data is underway but already it shows coherence to the themes established previously in literature review such as issues of funding, engineering curriculum and methods, accreditation, industry and professional bodies' involvement and politics. There are also some new themes and sub-themes that have emerged such as the relevance of practical training, transition into the profession which are to be followed up in the future.

IV. Expected Outcome and Conclusion

It is expected that at the conclusion of the research, clear and specific statements of procedure to be followed for a curriculum will be established to inform a procedure for designing a curriculum with provision for the local context on which the curriculum is applied. Hence meeting the research's objective "to develop a systematic procedure to design a curriculum and methods of teaching and learning to develop an internationally recognized professional engineer". The procedure will involve a set of the requirements that will have to be met by a curriculum in order for it to be locally appropriate and sustainable, for development of an internationalised engineer in Tanzania and Africa in general.

Further the research anticipates to highlight current generic local and internationally recognized skills for 21st century engineers that are relevant to African engineers hence attest the generic skills for international engineers in the African context.

The research will also produce a more detailed account of challenges of internationalization of engineering education in relation to the ongoing global initiatives and developments in engineering education from the perspective of different engineering education stakeholders such as academia, industry, practicing engineers and professional bodies.

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Harmonization of Engineering Qualifications through South-South Cooperation in Africa

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***Abstract* - The practice of engineering began in many African countries before they became independent nations. A review of the distribution of graduates in twenty three African countries showed that about 9 % were graduates of engineering programmes. The educational systems for training of engineers, technologists, technicians and craftsmen vary from one African country to another depending on the countries by which they were colonised before independence. To create mobility among African engineering personnel and engender sustainable economic development, harmonizing engineering qualifications in the continent is inevitable. Engineering registration boards of various African countries will have to agree on: having similar learning outcomes for engineering students; duration of industrial experience needed by a graduate engineer to qualify for registration; and number of credits to be earned each year to meet requirement for mandatory continuing professional development. COREN and some other organizations have made some efforts recently on harmonization of engineering qualifications in Africa. If international mutual recognition agreements from such efforts are honoured in Africa, it will help the continent to progress towards achieving agenda 2063 vision of the African Union.**

Nomenclature

Abbreviations
ACEN - Association for Consulting Engineering in Nigeria
ANSTI – African Network of Scientific and Technological Institutions
AQRM - African Quality Rating Mechanism
AU- African Union
BMAS - Benchmark Minimum Academic Standards
CAMES - Conseil Africain et Malgache Pour l'enseignement Superieur
CODES - Consortium of Organisation for Development of Engineers in the South
COREN - Council for the Regulation of Engineering in Nigeria
EAC - East African Community
ECSA - Engineering Council of South Africa
FEIAP - Federation of Engineering Institutions of Asia and the Pacific
ISTIC - International Science, Technology and Innovation Centre for South-South Cooperation under the Auspices of UNESCO
LMD - Licence-Master-Doctorate
MERCOSUR – Mercado Comun del Sur (Southern common market)
NBTE - National Board for Technical Education
NSE - Nigerian Society of Engineers
NUC - National Universities Commission
PWD - Public Works Department
SACPE - South African Council for Professional Engineers
UNESCO - United Nations Educational, Scientific and Cultural Organization

1. Introduction

The results obtained from a regional survey of the problems facing higher education in Africa showed that the fourth among the top ten challenges to quality higher education in the continent is lack of regional quality assurance framework and accreditation system [1].

A review of the distribution of graduates in 23 African countries showed that only about 9 percent were graduates of engineering programmes and it was found that many countries do not yet have regulatory agencies for quality assurance and accreditation of higher education programmes [1]. Whereas Nigeria has the National Universities Commission (NUC) and National Board for Technical Education (NBTE) as well as professional bodies to regulate higher education in Universities and Polytechnics. The agenda 2063 Vision of the African Union (AU) is "an integrated, prosperous and peaceful Africa, driven by its own citizens and representing a dynamic force in the global arena" [2].

A major means of realizing this vision is by strengthening higher education in Africa through [1]: establishment of harmonized higher education systems across the continent; strengthening higher education capacity through innovative collaboration; using agreed benchmark of excellence to systematically improve the quality of higher education; and making the mobility of graduates and lecturers across the continent easier.

To attain the vision of an integrated and prosperous continent where mobility of graduates is facilitated with economics and infrastructural development driven by Africans, it is necessary to harmonize engineering qualifications in Africa.

The aim of this paper is to briefly discuss the historical development of engineering practice and training of engineering personnel in Nigeria and make a proposal on harmonization of engineering qualifications in Africa.

2. Training of the earliest Engineering Personnel in Nigeria

Early in the 20th century the Public Works Department (PWD) Technical School was established in Lagos to give three-year training to students after secondary school to produce technicians. The Higher College Yaba was established in 1933 – 34 to train very good students from the best secondary schools where science subjects were well taught, first for two years up to the London Intermediate level, followed by another two-year course in engineering to produce "African" or "Assistant" Engineers who were placed on salaries 31 % lower than the salary of Nigerian graduate engineers trained abroad [3]. A few of the products of the PWD Technical School and several students of Yaba Higher College before or after completing the college diploma programme had scholarship to go abroad to earn university degrees and industrial experience to become professional engineers.

The University College of Ibadan which was established in 1948 admitted students who had completed secondary school into the first two years of engineering degree programme after which students who performed satisfactorily were awarded intermediate B.Sc. and admitted to British Universities to complete the remaining three years of the engineering degree programme [4].

The Nigerian College Zaria which ran engineering programmes, was established in 1955 and five sets of students graduated from there with B.Sc. (London) External degree from 1960 – 1964 [5].

A few years after Nigeria gained independence, in 1960, four universities were established which ran engineering programmes. The first set of students to be awarded Nigerian university degree in engineering graduated from Ahmadu Bello University in 1965. Several more universities were established in the 1970's and the decades that followed. There are currently over 130 universities in Nigeria with 46 of them running engineering programmes accredited by Council for the Regulation of Engineering in Nigeria (COREN). See Table 1.

Table 1: List of Nigerian Universities running Engineering Programmes

S/N	UNIVERSITIES	YEAR ESTABLISHED	OWNERSHP
1	Abubakar Tafawa Balewa University, Bauchi	1988	Federal
2	Afe Babalola University, Ado Ekiti	2009	Private
3	Ahmadu Bello University, Zaria	1962	Federal
4	Akwa Ibom State University, Nkpot Enin	2004	State
5	Ambrose Alli University, Ekpoma	1980	State
6	Anambra State University, Uli	2000	State
7	Bayero University, Kano	1975	Federal
8	Bells University of Technology, Ota	2005	Private
9	Caritas University, Amorji-Nike	2005	Private
10	Covenant University, Ota	2002	Private
11	Cross River State University of Technology, Calabar	2004	State
12	Ekiti State University, Ado-Ekiti	1988	State
13	Enugu State University of Science & Technology, Enugu	1981	State
14	Imo State University, Owerri	1992	State
15	Federal University of Agriculture, Abeokuta	1988	Federal
16	Federal University of Petroleum Resources, Effurun	2007	Federal
17	Federal University of Technology, Akure	1981	Federal
18	Federal University of Technology, Minna	1982	Federal
19	Federal University of Technology, Owerri	1980	Federal
20	Federal University, Oye-Ekiti	2011	Federal
21	Igbinedion University, Okada	1999	Private
22	Kano State University of Science & Technogy, Wudil	2000	State
23	Kwara State University, Malete	2001	State
24	Ladoke Akintola University of Technology, Ogbomoso	1990	State
25	Lagos State University, Ojo	1983	State
26	Landmark University, Omu-Aran	2011	Private
27	Madonna University, Okija	1999	Private
28	Michael Okpara University of Agriculture, Umudike	1992	Federal
29	Moddibo Adama University of Technology, Yola	1988	Federal
30	Niger Delta University, Wilberforce Island	2000	State
31	Nigerian Defence Academy, Kaduna	1985	Federal
32	Nigerian Turkish Nile University, Abuja	2009	Private
33	Nnamdi AzikiweUniversity, Awka	1992	Federal
34	Obafemi Awolowo University, Ile-Ife	1962	Federal
35	Olabisi Onabanjo University, Ago-Iwoye	1982	State

36	Osun State University, Osogbo	2006	State
37	Rivers State University of Science & Technology, Port Harcourt	1979	State
38	University of Agriculture, Makurdi	1988	Federal
39	University of Benin, Benin City	1970	Federal
40	University of Ibadan, Ibadan	1948	Federal
41	University of Ilorin, Ilorin	1975	Federal
42	University of Lagos, Lagos	1962	Federal
43	University of Maiduguri, Maiduguri	1975	Federal
44	University of Nigeria, Nsukka	1960	Federal
45	University of Port Harcourt, Port Harcourt	1975	Federal
46	University of Uyo, Uyo	1991	Federal

Source: COREN Headquarters, Abuja, Nigeria (2015)

3. History of Engineering Practice and Emergence of Engineering Institutions and Societies in Nigeria

The practice of engineering began in Nigeria between 1855 - 1889 (more than 70 years before independence), with construction of roads, housing projects, port facilities and waterworks in Lagos by expatriate engineers and the first engineering consultancy firm, Messrs. Shelford Consulting Engineers started practicing in Nigeria earlier than 1898 [3].

Herbert Heelas Macauly who was elected an Associate Member of the British Institution of Civil Engineers in December 1893, was the first Nigerian and probably the first in the whole of black Africa to qualify as a professional engineer [3].

For progress in their careers, the early Nigerian engineers during Colonial era sought to become members of the British Institutions of engineers. The Institutions of Civil, Mechanical and Electrical Engineers established the West African Joint Group in 1953 – 1954 with branches in Ghana and the three regions in Nigeria to take care of the interest of members who practiced in West Africa and also operate a joint preliminary examination for the admission of new members [3]. The few Nigerian engineers that belonged to this Group could not relate well with their expatriate colleagues because of racial antagonism. This made it necessary for Nigerian engineers to form a professional society of their own.

The Nigerian Society of Engineers (NSE) was formed in United Kingdom between June 1957 and February 1958 when the inauguration ceremony took place at the Nigeria House in London. At first the founding fathers were concerned with meeting the peculiar needs of engineering students studying in the U.K. and the graduate engineers undergoing practical training to become chartered engineers, as well as overcoming the challenge of racial discrimination experienced by Nigerian engineers as they practiced their profession in Nigeria [3].

The Association for Consulting Engineering in Nigeria (ACEN) was formed in 1971 by a group of senior engineers in the private sector to ensure that the ethics of the engineering profession was observed by consulting engineers. ACEN is closely linked with the NSE.

The NSE has 62 branches located in many towns spread throughout the 36 States and the Federal capital territory in Nigeria. Apart from these branches, members of the NSE have over the years formed institutions for various specialties of Engineering such as Nigerian Institution of Mechanical Engineers, Nigerian Institute of Structural Engineers, Nigerian Society of Chemical Engineers and Nigerian Institute of Agricultural Engineers. These are the divisions of the NSE. At present, there are 20 such divisions in the NSE.

4. Engineering Regulation Boards in Africa

COREN was established by decree 55 of 1970 as Council of Registered Engineers of Nigeria and its name was amended by decree 27 of 1992 as the Council for the Regulation of Engineering in Nigeria to include registration of technologists, technicians and craftsmen in the mandate of COREN. The law establishing COREN is now in Cap E11 of the Laws of the Federation of Nigeria, 2004 as the Engineers (Registration, etc.) Act. The mandate of COREN includes:

- Accreditation of Engineering Programmes;
- Registration of Engineering Personnel and Firms; and
- Regulation and Control of Engineering Practice.

The names of Engineering Regulation Boards or Councils in some African countries and the year they were established are shown in Table 2.

Table 2: Names of Engineering Regulation Boards in Some African Countries

Country	**Names of Regulating Board**	**Year Established**	**Source of Information**
Botswana	Engineers Registration Board of Botswana	Act of Parliament 1998 came into force 1st May, 2009.	http://www.gov.bw/en/Minis...
Burundi	No competent Engineers Registration Board	–	
Ghana	Institution of Engineering & Technology, Ghana (Ghana Engineering Council)	1973	http://www.ietghana.org/
Kenya	Engineers Board of Kenya	2011	www.ebk.or.ke

	(Formerly Engineers Registration Board)		
Nigeria	Council for the Regulation of Engineering in Nigeria	1970	
Rwanda	No competent Engineers Registration Board	–	
South Africa	Engineering Council of South Africa (ECSA) (Formerly SACPE)	Promulgation of Registration as SACPE in 1969. Became ECSA in 1991.	http://www.ecsa.co.za/de...
South Sudan	South Sudan National Engineering Council	2012	http://allafrica.com/stories/...
Sudan	Sudan Engineering Council	1977	www.ilo.org/.../...
Tanzania	Engineers Registration Boards of Tanzania	1997	http://www.erb.go.tz/index.php/about-us
Uganda	Engineers Board of Uganda	2013	http://www.erb.go.ug/
Zambia	Engineers Registration Boards of Zambia (Engineering Institution of Zambia)	2010	http://www.eiz.org.zm/home/

5. Harmonisation of Standards through South-South Cooperation in Africa

The definition of South-South cooperation by the UN states [6]:

"South-South cooperation development is a process whereby two or more developing countries pursue their individual and/or shared national capacity development objectives through exchanges of knowledge, skills, resources and technical know-how, and through regional and interregional collective actions, including partnerships involving governments, regional organizations, civil society, academic and private sector, for their individual and/or mutual benefit within and across regions. South-South cooperation is not a substitute for, but rather a complement to, North-South cooperation"

To create mobility among the continent's engineering personnel and engender sustainable economic development, harmonizing engineering qualifications in Africa is inevitable. This can best be carried out on the basis of the sub-regions in Africa or on the basis of lingua franca. Benedict Mukama at the ISTIC-UNESCO-FEIAP International Conference/Forum/Seminar on UN Post 2015 Development Agenda held at Kuala Lumpur from 25 – 27th May 2015 gave a progress report on the mutual recognition agreement of Engineers Registration Board of the Burundi, Kenya, Rwanda, Tanzania and Uganda (the five-member countries of East African Community) [7]. Nick Clark reported that Algeria, Tunisia and Morocco (the French-speaking Maghreb countries of North Africa) and an organization called CAMES covering most of Francophone African higher education have been working on aligning the degree structures in their universities to conform to the licence – Master – Doctorate (LMD) system to facilitate mutual recognition of qualifications and promote academic mobility among staff and students [8]. Engineering associations and registration boards can leverage on this existing arrangement to harmonise engineering qualifications in these francophone countries.

Engineering Institutions and Societies registration boards in English-speaking countries in West Africa, namely: Nigeria, Ghana, Liberia and Sierra Leone, can work together to harmonise engineering qualifications in their countries to facilitate mutual recognition agreement and promote professional mobility. Similar arrangement can be made for Central Africa and Southern Africa sub-regions. African Union, African Network of Scientific and Technological Institutions (ANSTI) and UNESCO should also be involved in facilitating harmonisation of engineering qualifications through south-south cooperation in Africa.

6. Relating the Proposal to Washington, Sydney and Dublin Accords

The Washington Accord, which was established in 1989, is an international agreement through which graduates of accredited engineering programmes in any of the signatory countries are recognized by other signatory countries as having met the academic requirements for registration as professional engineers or chartered engineers. The accord only covers the academic requirements that are part of the licensing process by the regulatory bodies in the signatory countries. The Engineering Council of South Africa (ECSA) which is the only signatory from Africa was admitted as a signatory accreditation body of Washington Accord in 1999 [9]. The Washington Accord currently has 18 signatory countries and 6 provisional status members [10].

On 25th June 2001, ECSA and other Engineering organizations from 6 other countries signed the Sydney Accord for the international recognition of Engineering Technology Academic Programmes for licensing Engineering Technologists in signatory countries. Engineering Technologists are variously called Certified Engineering Technologists, Applied Science Technologists, Associate Engineers, Professional Technologists (Engineering) and Incorporated Engineers in the signatory countries [9].

The Dublin Accord, which is an international agreement for the recognition of the qualifications for registration as

Engineering Technicians, was established in year 2002 by the engineering organizations of four countries including South Africa [9].

Cheong has observed that Washington Accord with their condition for admission of a new signatory being unanimous approval of all signatories, "gives the unmistakable impression of an exclusive club keeping out membership from other countries especially developing countries" [11]. This has made regional organizations like the Federation of Engineering Institutions in Asia and Pacific (FEIAP) to take the initiative in undertaking accreditation of engineering qualifications in some South countries to international standard [11]. Cheong [11] also reported that sub- regional accreditation of engineering education is going on well in MERCOSUR, the trade block in South America consisting of five full member nations (Argentina, Brazil, Paraguay, Uruguay and Venezuela) and six associates countries (Bolivia, Chile, Peru, Colombia, Ecuador and Suriname).

The idea of using benchmarks of excellence different from those used in developed countries is not new. Okebukola [1] reported that African Union Commission developed a framework for harmonization of higher education programme in Africa which involves "establishment of an African system to measure and compare performance of higher education institutions" called the African Quality Rating Mechanism (AQRM). The reasons for wanting to have AQRM are [1]:

- Using a set of criteria for comparing the performance of higher education institutions " that takes into account the unique context and challenges of higher education delivery on the continent";
- Facilitating improvements in higher education delivery in Africa making use of objective measures of performance; and
- Making higher institutions in the continent compete more effectively at the global level while making a case for reviewing the basis on which those global systems operate.

7. What Harmonization of Engineering Qualifications will involve

The three important aspects of quality assurance for professional engineers are: accreditation of programmes, certification of engineers, and continuing professional development (life-long learning) [12]. There is need for harmonization in all the three aspects.

It was reported that Africa has over 2,450 post-secondary institutions with over 65% of them made up of universities and the rest being polytechnics, colleges of education, vocational and technical institutes [1]. These institutions have diversity in language of instruction with French being used francophone countries, Portuguese in lusophone countries and English in anglophone countries.

The educational systems for training engineers, technologists, technicians and craftsmen vary from one African country to another because each country tends to follow the educational systems of the country by which it was colonised before independence. Harmonization of engineering qualifications in Africa involves making the systems of training engineering personnel and the rules guiding professional practice similar in the different countries, at least to some extent.

The Engineering registration Boards of various countries in Africa will have to agree at least on having similar learning outcomes of international standard for engineering students even if there are variations in curriculum due to sovereignty of each nation and autonomy of each university.

The duration of industrial experience needed by a graduate engineer to qualify for professional registration will have to be the same all over the continent. The number of credits to be earned each year for mandatory continuing professional development to meet the condition for renewal of practicing licence will also be about the same in all Africa Countries. Courses, workshops, seminars and conferences to be attended to earn such credits can be run internationally so that an engineer can attend such training in any country in the continent.

It will be necessary to work out acceptable code of ethics and guidelines/principles of mutual cooperation between organisations based in different countries. There should also be arrangement for conflict resolution between different parties. Dharmawardhane [13] pointed out that "South-South relations are meant to be non-exploitative, reciprocal, and based on respect for independence, sovereignty, and territorial integrity".

Harmonization does not mean making the training of engineers, technologists, technicians and craftsmen uniform all over the continent. Unique core values of individual institutions in various countries should be preserved. Harmonization involves fostering collaboration and partnership among engineering institutions leading to mutual recognition of engineering qualifications earned by various cadres of engineering practitioners in African countries.

8. Progress towards Harmonization

In the last few years, ISTIC under the auspices of UNESCO has been involved in mobilization for accreditation of engineering education qualifications and in South countries to the level of international standards. The chairman of the governing board of ISTIC, Lee Yee Cheong has proposed the formation of the Consortium of Organisation for Development of Engineers in the South (CODES) for this purpose [7].

The steps taken so far are:

- Development and circulation for review and comments of the COREN Benchmark Minimum Academic Standards (BMAS) document among many South-South cooperation country Engineering Associations and Regulatory Boards, ISTIC and the UNESCO Regional offices in Jakarta and Abuja;
- Signing of a Memorandum of Understanding (MoU) with ISTIC by COREN in August 2015 for collaboration in various ways towards linking Africa with Asia and Asia Pacific;
- UNESCO Regional office in Abuja making a promise to support this effort by bringing together all stakeholders in the sub-region to a meeting for the purpose of designing a joint accreditation protocol;
- UNESCO Regional office partnering with COREN on a joint project to foster gender balance in engineering education and practice with COREN collaborating with the Association of Professional Women Engineers in Nigeria (APWEN) to create a forum for mentoring female engineers and drive the process of Science

Technology Engineering and Mathematics (STEM) education in institutions in Nigeria; and

- Acceptance by the UNESCO Regional office to actively participate in COREN advocacy for the resuscitation of Technical colleges in Nigeria for training craftsmen.
- COREN in collaboration with UNESCO Jakarta, UNESCO Abuja, ISTIC and FEIAP organizing a high level policy forum on engineering accreditation and mobility in Africa in Abuja from July 18 – 22, 2016.

9. Challenges

Issues related to national sovereignty in countries with diverse cultures and different lingua franca can hinder progress towards harmonisation of engineering qualifications in Africa. In addition there are variations in curriculum and quality of education across various African countries and there is also the challenge of mobilising adequate fund for such a project.

Not all African countries have the legal and institutional framework for the engineering profession. For example, when a mutual recognition agreement was to be signed under the auspices of EAC in Arusha on 7th December 2012, to enable engineers within the EAC to practice freely across borders, Rwanda and Burundi could not participate because they did not have Engineers Registration Board [14]. Countries that do not have Engineers registration boards will have to pass such laws to be able to participate in harmonization of engineering qualifications in Africa.

Disparity in salaries and wages across borders can also pose a challenge to mobility of engineering practitioners in Africa.

10. Advantages of Harmonizing Engineering Qualifications in Africa

Engineering students, graduate engineers will find it easier to secure places in other countries in Africa, for industrial training and postgraduate industrial experience, respectively.

Mobility of engineers will be facilitated and an engineer in one country can easily go into joint venture with a colleague in another country who has more expertise on the type of project at hand.

One of the clauses under the agreement of Washington Accord states that best practices will be identified and their implementation will be encouraged [9]. It was also stated in another clause that there will be mutual monitoring and information exchange among signatories [9]. Thus harmonization of engineering qualifications leading to mutual recognition agreement will appreciably enhance the quality of engineering education, registration of engineering personnel and engineering practice in Africa.

Recommendations and Conclusion

A pre-requisite for interested African countries to arrive at an accord is that the processes, criteria, policies and procedures for granting accreditation to engineering academic programmes be comparable. By this proposal, African countries may consider having one accord to cover all the four categories of engineering practitioners (engineers, engineering technologist, engineering technicians and engineering craftsmen) instead of having one accord for each cadre.

It is recommended that a workshop be held to bring together representatives of Engineering Councils or Registration Boards and National Societies or Institutions of Engineers of interested African countries for the purpose of dialogue to work out the modalities for establishing the accord.

If engineering qualifications are harmonised and international mutual recognition agreements are honoured in Africa, the standard of engineering practice will be raised, engineers practicing in the region will tend towards "engineers without borders", and Africa will make progress towards becoming an integrated prosperous and peaceful continent driven by its own citizens as stated in Agenda 2063 vision of African Union.

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Curriculum Review from the Dual Prism of Academia and Industry

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***Abstract*— A framework for the review of engineering curricula based on an analogy to the dual prism adaptation process observed in neuroscience is proposed. The framework acknowledges the necessity to develop a dual-adaptation mechanism that can quickly shift between academic or textbook skills and the competences required by industry, where textbook examples frequently fail to provide comprehensive solutions to practical problems. The application of the framework is demonstrated through the review of a curriculum for a microcontroller's module at third year level in alignment with ECSA exit level outcomes and industry's expectations.**

***Index Terms*— autonomous line-follower robot, constructive alignment, curriculum review, engineering education, microcontrollers curriculum, systems approach**

I. Introduction

IN neuroscience there is a dual-adaptation experiment that investigates the interaction of humans within a dynamic environment that requires rapid adjustment between two different modes of operation. A specific experiment that is performed within this context uses dual prisms to investigate adaptation of visuo-motor mappings in a pointing task where dual prisms are applied to offset the visual field. In this task the visuo-motor system needs to re-map to adjust to the offset image so that the subject may accurately point to a target, but it also needs to maintain its original mapping to enable subjects to quickly change between the unshifted and dual prism-shifted modes of pointing [1]. This experiment provides an apt analogy to describe the objectives for the review of an engineering curriculum, i.e. to provide students with a dual-adaptation mechanism that can quickly shift between academic, or textbook skills and the competences required by industry, where textbook examples frequently fail to provide comprehensive solutions to practical problems.

The diagram in Fig. 1 illustrates a framework against which an engineering curriculum may be developed or reviewed to enable students to adapt from an academic environment to new challenges that they will face in industry. The academic development of a student is represented by the small triangle labeled *Academia* on the right showing cognitive development according to the revised Bloom's taxonomy [2]. The development of levels of expertise that are required to excel in an industrial environment is mirrored in the small triangle on the left, labeled *Industry*. Industry's triangle also follows the basic progression of Bloom's taxonomy with a development from lower cognitive skills to advanced abilities that depend on engineers' experience and skills to perform complex evaluations of their and their peers' work. Between these two triangles lies a dual prism that introduces an offset between textbook knowledge acquired in a purely academic setting and the engineering know-how that is required to effectively engage in real-world projects in an industrial setting. The arrows between academia and industry's triangles indicate the adaptive ability of students that needs to be developed and nurtured within a well-designed curriculum. Students need to develop the ability to effectively progress between academic development of skills and the implementation thereof in industry. The academic and industry objectives are contained inside a large triangle that represents constructive alignment [3] of outcomes, assessment and the teaching and learning strategy, yet another prism that shapes an effective curriculum.

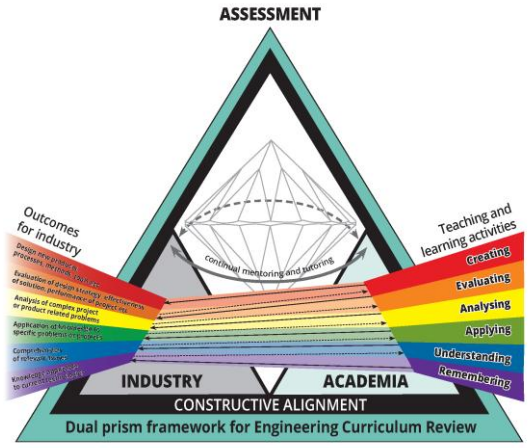


Fig. 1. A dual prism framework against which an engineering curriculum may be reviewed to allow bidirectional adaptation between academia and industry based on the revised Bloom's Taxonomy [2, 4] and Biggs' model of constructive alignment [3].

In this paper the dual prism approach to engineering education is applied to the review of a curriculum for a third year microcontrollers module to demonstrate the dual prism approach to engineering education.

II. Context for the Review of a Curriculum

Microcontrollers, popularly known amongst students as its module abbreviation EMK310, is a third-year module, taken by all Electrical, Electronic and Computer Engineering students in the Faculty of Engineering, Built Environment and Information Technology at the University of Pretoria. It educates students in the basics of microcontroller system design and implementation.

The dual-objectives of the module are to provide a solid foundation in microcontroller architecture, programming and interfacing with the real world and to align this academic

foundation with industry's expectations of the expertise with which students exit our degree programs. To this end, the outcomes of the module are strongly aligned with a number of the Engineering Council of South Africa's (ECSA's) exit level outcomes (ELOs). Outcomes such as problem solving (ELO1), application of scientific and engineering knowledge (ELO2), design (ELO3), engineering methods and tools (ELO5), communication (ELO6), and teamwork (ELO8) are explicitly developed through the teaching and learning strategy.

The content of the module is hardware-oriented, i.e. although there is an explicit focus on the development of firmware *Assembly language* is used as a vehicle to teach microcontrollers because it relates closely to the hardware of these devices. Further emphasis is placed on the peripheral circuits and systems that invariably form part of a microcontroller system. If microcontroller instruction is begun with higher level programming languages students may potentially be robbed of the opportunity to become intimately familiar with the registers and structure of these devices. This knowledge, in turn, is crucial for the engineer who wishes to gain proficiency in the design and implementation of microcontroller systems at all levels of complexity.

Applying the dual prism framework to engineering teaching and learning in microcontroller system design is vitally important because

- the majority of EECE graduates will eventually work in microcontroller system design,
- our graduates are frequently rated based on this single skill-set, and
- the module is presented at exit level, i.e. there is no formal microcontrollers follow-up module before students graduate.

III. Review of a Curriculum for Microcontroller Education

The review of the microcontrollers curriculum, and with it the redesign of the teaching and learning strategy, commenced in 2005. The presentation style of the module consisted of lectures that covered some basic aspects of microcontroller architecture and microcontroller system design while practical assignments focused on simple microcontroller implementations in Assembly language without any formal guidance in Assembly language programming. In addition, any firmware that had to be written for tests and exams were written on paper, which made both writing the tests and assessment time consuming, ineffective and frequently inaccurate. Over the past decade the digital device market has exploded world-wide, driving a need for more engineering graduates that are equipped with microcontroller system design skills. To address this need it was necessary to review the microcontrollers curriculum. At the same time an opportunity was created to empower our students to excel in the microcontroller system design industry. Since our students come from diverse backgrounds and have different skills levels, even at a third-year level, a review of the curriculum within this context and with it the teaching and learning strategy was inevitable. In addition, this is a core/fundamental module pitched at exit level outcome standard/criteria, i.e. it is the last formal module in microcontrollers in the electrical, electronic and computer engineering degree programmes. We thus have to ensure that students who pass the module are equipped with the skills that they will need in industry.

Over the first few years of offering the module, a number of areas were identified to justify the redesign of the teaching and learning strategy. These were, in broad terms, the following:

- The scope of the module had to be expanded to include design aspects that relate to interfacing a microcontroller system to the real world instead of only focusing on the microcontroller device itself, i.e. the focus had to shift from microcontroller systems design to a more holistic embedded systems design.
- The tools for the practical tuition had to be reconsidered so that it could be aligned with industry standards.
- The assessment strategy had to be redesigned to (i) allow students to access the tools that are available through the integrated software development environment (IDE), (ii) improve grading efficiency and accuracy, and (iii) allow assessment of students' ability to apply their knowledge and skills to a realistic engineering problem.
- Since the school landscape changed significantly over the past two decades, the approach to teaching the practical component of the module had to be revised, as many students were lost if left alone to master the programming component of the module.

These initial interventions were the catalysts for most of the subsequent developments in the module that are described in the remainder of this paper.

Another major challenge that emerged in engineering education in general over the past few years is that students do not want to, or do not see the use of being challenged at higher cognitive levels. In the engineering environment or industry this affects students' ability to analyse a problem from a scientific viewpoint and formulate a possible solution in terms of a design (synthesis). It also affects their ability to critically evaluate the system for, among others, effectiveness, robustness and appropriateness of the solution. One of the many reasons that might contribute to this is the instantaneous and diverse availability of information through the internet. While the internet can be a very powerful resource, it becomes a severe handicap when a student's ability to create solutions to problems becomes dependent on the availability of ready-made, online solutions from which a system may be "hacked" together. A review of the curriculum thus also needed to address this challenge explicitly and effectively to ensure that students are able to construct a solution from first principles.

A. Reviewing and creating infrastructure to support curriculum changes

Review of a curriculum necessarily includes a review of the infrastructure that is required to support the accompanying teaching and learning strategy. Presenting a practically oriented module to a large number of students generates a variety of infrastructure requirements.

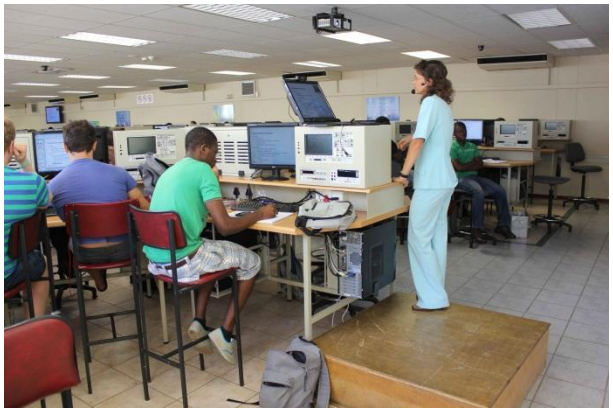
1) Phasing in state-of-the-art tools

To facilitate a hands-on approach, the tools for the practical

sessions were reconsidered. In 2005, students used a rudimentary microcontroller programmer that they had to construct from a component kit. These programmers were unreliable and students spent many hours trying to sort out the tool instead of learning the content of the module. After negotiations with a leading microcontroller manufacturing company, a commercially available programmer was introduced as prescribed hardware for the module in 2006. The implication is that each student has his/her own hardware tool available 24/7 instead of sharing resources in the campus laboratories. This step proved to be one of the best interventions in the module thus far and allows students to become familiar with the type of tools that would be available in an industrial setting. Since students are always supplied with the latest upgrade of the tool, they educated using current technologies.

2) Expanding classroom-capacity

Another requirement to facilitate a hands-on approach is presentation of lectures in a computer laboratory where students can participate in interactive lectures. An increase in student numbers in recent years posed a challenge to this approach. To avoid students having to share computers and thus only watching the interactive lectures instead of participating therein, it was decided to expand the capacity of the original 144-seater classroom-laboratory by installing bi-directional audio and video (AV) links to two additional computer laboratories in a separate building. The lecture is presented in the main laboratory and broadcast to the other two laboratories via the AV-link. The approach to re-invent the way in which existing infrastructure is utilised is effective with students who prefer to be close to the lecturer attending the lectures in the main laboratory and students who prefer the better view from the data projectors in the remote laboratories attending the lecturers in those laboratories. This relatively low-cost initiative is expandable to all the laboratories in the department, thereby providing ample capacity for increased student numbers.



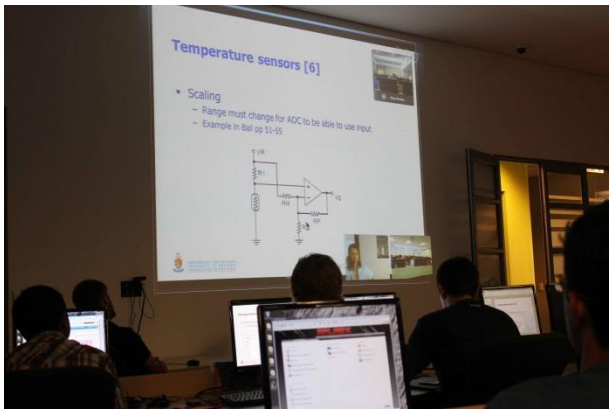


Fig. 2. Multi-laboratory classroom setup showing the lecturer in the main laboratory (top). The middle and lower pictures show students in the remote laboratories and the view that they have on the presented material and the lecturer.

3) Network support for tests and exams

To facilitate submission of soft copies of coding tests and examinations as well as the ability to have students write examinations on the PCs in the laboratories, a network solution was set up to (i) allow downloading of coding templates and other relevant materials from a dedicated examination server, (ii) closing all network connections to the PCs during the examination so that students do not have access to one another, the internet or external consultants, and (iii) uploading the answers to the examination server again. The reason for not using an interface such as clickUP (UPs in-house name for Blackboard) for uploading and downloading tests, is that students are allowed limited access to resources, i.e. only the resources on the laboratory computers and not all material available in the clickUP module. Everything a student needs to design a system and implement the firmware is thus made available, but the tendency to depend on ready-made solutions from the internet is addressed and prevented.

B. Creating a support system

To present a module at the level described in this document, a support system is of immense importance. For the microcontrollers module the support system comprises a very competent laboratory instructor, IT support, a team of assistant lecturers appointed from the department's postgraduate students, tutors appointed from final year students who have completed the module the previous year and administrative

staff.

All these people contribute to the development, implementation and maintenance of existing and new infrastructure, as well as to the day-to-day tasks associated with presentation of the module. The role of the lecturer is to justify, set up, manage and maintain the support system to allow effective presentation of the module and continuity of tasks as the assistant lecturers and tutors may vary on a yearly basis.

Support from the head of the department (HoD) as well as the dean of the faculty is also important, since students tend to protest, at least for a while, when new ideas are introduced. If managers do not share the lecturer's vision, effective review of a curriculum could be obstructed instead of being encouraged.

For this specific module, support from industry contributes significantly to the success of the teaching and learning strategy and is highly regarded [5]. Support in the form of discount on development boards to enable each student to own his/her own hardware platform that is permanently available, and providing samples of devices to support practical work, provides a sustainable model to facilitate the hands-on approach that is necessary to develop microcontroller system design skills. Support from industry in the form of sponsorships for Race Day also provides encouragement and motivation for students to put in a lot of effort in mastering the learning outcomes through the development of their autonomous robotic vehicles. This initiative will be explained later in the document.

C. Reviewing module content and revising the teaching and learning strategy

1) Aligning content to outcomes as defined by industry's expectations

To align the content of the module with industry's expectations of the skills that a graduate engineer should possess, the scope of the module had to be expanded to include design aspects that relate to interfacing microcontroller systems to the real world instead of only focusing on the microcontroller device itself. This was done by including design strategies for various real world interfaces as the main theoretical component of the module. Students found (and still find) this change in approach very difficult, since the module evolved to build heavily on material that was learnt in preceding modules. This aspect of the module was specifically designed to provide an opportunity to teach and learn integration of multiple engineering concepts – a skill that is crucial when entering the final-year design project as well as industry the year thereafter.

With the introduction of a stronger focus on the development of coding skills in the module, the observation that students were lost if left alone to master the programming component of the module necessitated an intervention. The contact periods were divided into theory lectures, covering the material described in the paragraph above, and application lectures that use Assembly language as a vehicle to teach students the basics of microcontroller architecture and coding. These lectures made a remarkable difference to students' ability to apply theoretical skills in practical projects.

2) Introducing the systems approach

The systems approach was introduced for a number of reasons. The first reason was to save students time in tests and examinations by giving a single system to consider instead of a number of unrelated questions that would require a totally new thought process and thus "waste" time. The plan was to allow quicker understanding of the problem at hand by adding context. A second reason was to alleviate the boredom of manipulating bits and bytes on paper for no other reason than to score marks in a test or examination. However, it was found that students struggled with the approach, indicating a notable deficiency in their ability to integrate information into a single, novel context. This was an important discovery, since the ability to apply knowledge in context has a direct impact on an engineer's creative ability, i.e. his/her ability to function at higher cognitive levels. Based on this discovery, it was first decided to place more focus on the application of theoretical concepts in everyday systems during lectures and to base all assessment in tests and examinations on systems. Later, it was decided to include the practical aspect of the module into the systems approach as well, leading to the review and subsequent redesign of the practical assignment to focus on a single, comprehensive system. The redesigned practical provided an effective contextual platform to which the theoretical concepts in class could be related, i.e. we discuss the application of the theoretical concepts to our practical assignment in class.

Apart from the advantages of this approach pointed out already, the following contributions to the teaching and learning strategy are relevant:

- The approach facilitates integration of aggregated knowledge from the first and second years. This is another crucial intervention, since students frequently think that once a module has been completed, they are "done" with it, not necessarily accepting the fact that the content has to be taken to subsequent modules. Without context, many modules in the undergraduate programmes are, in fact, not really integrated and perpetuate the idea of "completing" a module, not requiring the concepts and skills to be transferred to the next level.
- Exposure to the systems approach in the third year prepares students for their final-year project, where each student has to complete a comprehensive engineering capstone project to demonstrate competency in the required engineering skill set. Having worked through several systems in tests and examinations, as well as a comprehensive system in a group setting, thus provides an entry point into the approach that needs to be followed in the final year.
- The systems approach also demonstrates the nature of engineering tasks to students, thereby preparing them for industry. In addition it provides the opportunity to expose students to skills that might not be directly taught, such as what to do if information on an aspect of the system seems incomplete – a typical scenario when non-technically

trained clients request the design of a custom system.

Through implementation of the systems approach, theoretical and practical aspects of the module were thus effectively aligned with the intended outcomes.

D. Redesigning the practical assignments

As a result of the high standards that were phased in and maintained in the module, students started to dread the module. It was necessary to change the perception of the module among students from one where they feared the module to one of excitement and anticipation. This was done by redesigning the practical aspect of the module to have the students design and build an autonomous line-following robot in teams and have the teams compete in a race at the end of the semester.

Additional advantages of the redesigned practical assignment are that

(i) students have the opportunity to integrate their engineering knowledge, tools and skills that they acquired to this point into a practical problem that is both fun to work on (thus encouraging students to put additional effort into the project) and technically challenging (thus providing an opportunity to gain technical experience). This approach stimulates the development of adaptation skills to allow progression from academic competences to industry-required skills as illustrated in Figure 1.

(ii) it introduced the systems approach into the practical component with the associated advantages.

(iii) a system could be designed and implemented from first principles in a group setting to prepare students for their final-year project where they will also need to work through a project from start to finish, only on an individual basis.

(iv) by carefully specifying the system while allowing innovation in the method of implementation, the problem of internet-dependency is effectively addressed. There are very few similar assembly language implementations available on the internet and the specifications are purposely designed to exclude any existing material in an attempt to basically force students to make an effort to produce a novel design. This is indeed one of the most common "complaints" from students: they cannot find a comprehensive solution to the problem on the internet.

The practical assignment culminates in an annual Race Day, which is organised to be a professional event that celebrates the students' achievements. In the four years that Race Day was presented, the objective of changing students' perception of the module was achieved, with many students from junior years enquiring about the module and indicating that they could not wait to enroll for it. The positive feedback received from students who completed the revised curriculum and participated in Race Day suggested that students felt that they benefited from the module, that they perceived a sense of achievement when they passed the module and that they deemed themselves equipped with the necessary skills to successfully attempt a project requiring microcontroller system design.

Race Day also created the opportunity to involve a number of engineering companies (i.e. industry) either through sponsorships or via attendance of the event. A video and picture archive of past Race Day events can be found at http://www.ee.up.ac.za/main/emk310/index.

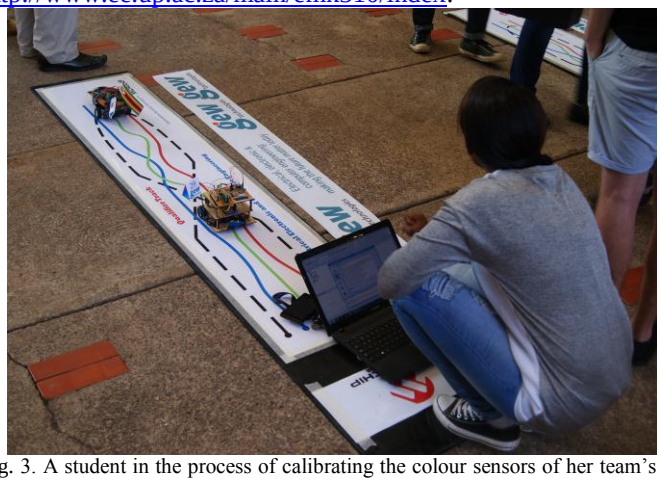


Fig. 3. A student in the process of calibrating the colour sensors of her team's autonomous line-follower robot car at the 2016 Race Day event.

E. A comprehensive approach to assessment

As mentioned, the assessment strategy was the starting point for the implementation of the systems approach in the module. Every question paper is designed around a central, authentic engineering system that needs to be developed within the context of a microcontroller system. Question papers cover the design of the external analog electronics that connect to the microcontroller system, e.g. analog scaling circuits to condition signals for digitization through an analog to digital converter, to calculating limitations of the system, e.g. the maximum bandwidth of a signal that may be sampled given the droop rate of the sample and hold circuitry of the onboard ADC, to the development of firmware to implement the system on a microcontroller using Assembly language.

All tests and examination question papers are designed with Bloom's taxonomy in mind to assess the level to which students have mastered the curriculum with specific reference to ECSA ELO's 2 and 3 (application of scientific and engineering knowledge and engineering design respectively).

The assessment strategy allows students access to the typical materials and tools that would be available should they encounter the equivalent of the test or examination assignment in industry. This includes documentation such as datasheets for the relevant components and devices, software programs such as Microsoft Excel and the integrated development environment (IDE) of the supporting microcontroller manufacturer for the development of firmware. This approach ensures that students' abilities may be tested in a simulated real-life environment, providing a more accurate assessment of their skills levels than when writing paper exams. Assessment of firmware solutions is also supported through the debugging capabilities of the IDE software. To improve grading efficiency, a highly-efficient, novel auto-grading system (AGS) was developed to grade both theory and firmware answers programmatically. The advantages of this approach are that (i) grading time is independent of student numbers, (ii) grading time is negligible compared to the time it takes to grade tests manually and, (iii) grading is consistent, accurate

and objective.

However, tests and examinations form only one part of the assessment strategy. While it does support a degree of adaptation between academic outcomes and industry expectations, it tends to be more academic in nature. Assessment thus also needs to include a strong component of practical skills evaluation that effectively addresses the progression to industry-ready skills. The design and construction of the autonomous line-following robots is broken down into three practical assignments that need to be demonstrated to a predefined level of achievement. The objective of this approach is to guide students through a number of manageable phases of the project and simultaneously create opportunities to tutor, mentor, assess, intervene, provide feedback and encourage throughout the course of the project. Students work in teams of up to four members which aligns with ECSA ELO 8 (teamwork)

For each practical there is a set of four to six minimum requirements that need to be met to pass the practical and to be allowed to progress to the next practical. These minimum requirements reflect basic competency levels based on industry's expectations, as well as the bare minimums to achieve a running autonomous line-following robot by the third practical. Students need to demonstrate at least half of the minimum requirements to be allowed one second attempt at demonstrating a specific practical, i.e. there is leniency for students who can demonstrate an attempt, but have not yet, at the time of the demonstration, managed to achieve all the minimum requirements.

ECSA ELO 6 (technical communication) is addressed through the requirement that students need to document their work in a laboratory notebook and need to prepare mini-posters to present their designs and the results achieved. The documentation is assessed by the evaluator at the demonstration for comprehensiveness, format, logic and structure. Figure 6 below shows the mini-posters being displayed in the laboratory during a demonstration session. Grading of mini-posters is based on peer assessment where each team needs to assess three other teams' posters. A self-assessment of the team's own poster then follows to allow students to evaluate and compare the quality of their work to that of their peers. This strategy supports the development of adaptation across the dual prism leveled at evaluation skills in Fig. 1.

Fig. 4. Gallery walk approach to grade mini-posters as an alternative to writing full technical reports.

F. Holistic approach to tutoring and mentoring

Because of the multi-faceted teaching and learning approach in the module, an effective and comprehensive tutoring system is very important. In Fig. 1 the supporting role that tutoring and mentoring plays to facilitate the development of the dual prism adaptation process between academia and industry is represented by the central location in the constructive alignment triangle. The tutoring system was developed to support students in the three different components of the module, i.e. theory, firmware development and practical assignments in an integrated manner.

One lecture period per week is dedicated to tutoring classes on theoretical and coding aspects of the module. These classes focus on system examples from previous tests and examinations. Since new tests and examinations are always set, the objective is to teach students the way that they should approach an unknown system, as would be expected in tests and examinations and adaptively, in industry. In addition, the autograding system for past tests and examinations is re-deployed as a computerised tutoring system (CTS) to assist students with preparation for tests and examinations. The system inherently encourages self-learning as well as small-group peer learning. Since tutoring in the traditional sense (i.e. by a human instructor) becomes an excessive load on teaching staff in large classes, a CTS may be used to address common tutoring needs, enabling staff to focus on more specific tutoring needs.

During weeks when there are no practical demonstrations, tutors are deployed in the laboratories to assist teams on a one-to-one basis with specific problems that they encounter with their practical work. These tutors are hand-picked from the top performers from the previous year's class to ensure that they are competent. The other advantage of having the top performers tutor is that they usually have a very positive attitude towards the module, which encourages and enthuses students.

Finally, a number of video tutorials have been recorded to allow students to work through material that is crucial for the success of the module, e.g. the first coding examples of the semester. This archive is expanded on every year and the first steps have been taken to translate transcripts of these videos to other languages in an attempt to provide a limited level of mother tongue support.

IV. CONCLUSION

In this paper a framework for curriculum review from the perspective of a dual prism adaptation process was proposed. The application of the framework was demonstrated through the review of a microcontrollers module at third year level. The outcomes of the curriculum and associated teaching and learning strategy may be assessed through

(i) the excellent coding proficiency that students attain in alignment with ECSA ELOs 1, 2, 3 and 5 and meeting industry's expectation that graduate engineers must be able to develop firmware for microcontroller-based systems,

(ii) students' ability to scientifically approach system analysis and design (ECSA ELOs 1, 2 and 3) and to critically evaluate their own work through the performance of their autonomous line-follower robots at Race Day, aligning with Bloom's evaluation level of cognitive ability,

(iii) the development of teamwork (ECSA ELO 8), reporting through means of mini-poster presentations (ECSA ELO 6) and peer assessment skills, and

(iv) the growing involvement of industry in the review process of the curriculum through feedback as well as endorsement of the teaching and learning strategy through hardware support and ongoing sponsorships to support the Race Day event.

ACKNOWLEDGMENT

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A Competency-Based Approach to Recruiting and Developing Academic Leaders – A Review

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Abstract-The definition of leadership in academia is very similar to the one in business settings: inspiring others, being a role model, being self-aware and self-reflective as well as being decisive, visionary, planning ahead and handling the finances. In summary leadership is described as the ability "to enable the success of other people". Given the fact that institutions of higher learning are being challenged as never before by many forces: the tough and uncertain economic climate, profound pressure in funding such as "# fees must fall" in South Africa, and unprecedented global competition for the best and brightest students and staff, one would assume that the rigorous processes used in recruiting business leaders would similarly be adopted by institutions of higher learning to recruit and develop their leaders. However, a review of recruitment of academic leaders determined that most universities recruit their academic leaders using the traditional approach based on seniority on the academic rank regardless of whether or not the candidates have proven leadership competencies. The few universities that recruit and develop their leaders based on their leadership competencies appear to have effective leadership. This paper reviews the recruitment and development of academic leaders using a leadership competency model as an approach that leads to effective academic leadership.

Keywords: Academic leadership, business setting, competence, leadership competency model.

1. INTRODUCTION

Given the multiple challenges that universities across the world are facing, it has been important for them to restructure their funding models to include activities such as entrepreneurship that are hitherto considered the realm of the business community. Success today requires universities to pursue excellence in the core functions of teaching and research, and, at the same time, to be more and to do more. Universities are being re-defined in many ways: as levers of social mobility, as engines of local economic growth, as founts of technological advances that are changing society. All this makes painfully clear that academics can't do all this by staying in their ivory tower of academia.

To be successful, universities now need top quality academic leaders and managers – be they heads of departments, deans of faculty, deputy/ pro-vice-chancellors and even vice-chancellors. There is a need for the leadership of the kinds of people who are willing to stick their necks out. However, in many universities leadership positions at the level of heads of department (HoDs) and faculty deans are held by a faculty member who willingly gives up most of the teaching and research activities and become a full-time administrator. Traditionally, these deans are voted into their positions by colleagues in their schools/ colleges based on their seniority. Depending on campus policy, it may be for a limited period of time. Most deans return to the faculty when their terms in office have expired. For them, leadership in the dean's position is complicated by the desire to bring accomplishment and excellence to the college, school or faculty [1] while keeping in mind that they will have to return to the faculty that they are shaping. For those deans who do not have to return to the faculty, and are normally recruited using a rigorous recruitment process, attention to leadership is more managerial/ professional in nature.

Academics by nature are people suited to working "in the laboratory" – scientific or otherwise – and delving into the intricacies of their specialty with diligence. Therefore, a university leader needs to be an academic to gain the respect of the academic staff he or she leads and to fully understand at the ground level the nature of the university's core intellectual functions. At the same time, a university leader needs to be an entrepreneur, able to make the bold business decisions demanded and to seize the initiative where required [2]. Although many professions within universities operate within a stable institutional context [3], the leaders of these institutions need to be able to adapt to a constantly changing environment and external influences. These skills cannot be learned in a day or on a week-end workshop but need to be developed over some time.

Academic leaders are often faced with the ambiguity in which they need to lead. Academic leaders must be able to adapt their leadership style when working with the different constituencies of the faculty and the university. A more facilitative leadership style is needed when working with faculty in the academic core and a more traditional line-authoritative style is needed when working with the administrative core [3]. Very often academic leaders need to work with both these types of employees which adds pressure on developing their own management skills. There is also constant tension in pursuing academic goals and having the obligation to perform administrative duties. "Having insufficient time to remain current in my discipline" is the number one stress for HoDs and ranked third for Deans [4]. The balance between pursuing academic goals and performing administrative duties leads to time constraints. These time constraints add to the challenge to adapt to new role and its environment, to master newly acquired skills and to function at an operational and strategic level.

Generally, academics do not aspire to do the job of a leader. In a study done by Oliver-Evans [5], it was reported that 70% of the HoDs did not want to do the job. The majority of HoDs see themselves as overburdened in a thankless job that detracts from their scholarly careers, in which their status, and thus their ability to implement leadership, has been eroded, and for which there is inadequate support from their administrative and academic colleagues. Most damaging is the perception that they may have lost the respect of their peers; their colleagues are grateful that the job of HoD is being done, but they are generally not admiring or respectful of the position.

Based on this background, this paper reviews the recruitment and development of academic leaders using a leadership competency model as an approach that leads to effective academic leadership.

2. CHALLENGES FACING ACADEMIC LEADERSHIP

According to Berg and Jaber [6] leadership in academia is facing the following challenges:

- Leadership in academia is sometimes a matter of leading independent researchers who do not want to be lead. There is scepticism towards leadership as a competency and why money is being spent on leadership development rather than on research.
- Leadership roles are sometimes perceived as a burden which needs to be carried by someone, and can be perceived as a threat of ruining a research career if too much of the individual's time is spent on leadership rather than on research.
- Combining the roles of subject matter expert and leader in one person, and finding the balance between these roles seems to be a challenge for many leaders in academia. Some leaders express fear of showing their weaknesses. This may hamper the ability and willingness to develop leadership skills.
- Expectations on leaders today are increasing throughout society. In academia, students and employees expect more active forms of leadership such as coaching and mentoring. This requires a different type of leadership that is less hierarchical and more team oriented than traditional leadership. Still the leader should be the subject expert and role model.
- A question raised is whether there are dissimilar requirements for leading academic staff and support staff? Furthermore, the perception of status difference between academic staff and support staff is a challenge, where academic staff have higher status than support staff; can a good leader bridge that difference?

According to De Jager [7] the challenges faced by deans of engineering faculties, focusing on innovative management methods and organisational processes include:

- The quality of teaching and learning;
- The quality of research and innovation;
- Staff recruitment, retention and development; and
- Faculty structure, governance and partnerships.

At the executive levels of university leadership, the challenges faced by the incumbents, i.e., deputy vice chancellors and vice chancellors in addition to the ones mentioned above are related to finance, brand of the institution and the political context. It is clear, therefore, that the expertise of academic staff in their areas of specialisation does not prepare them to navigate the challenges they face in their leadership duties. Therefore, the traditional approach of recruiting academic leaders based on seniority on the academic ladder is not able to address these challenges. An approach that is able to identify and develop the capabilities and competencies required to address these challenges is a necessity.

3. COMPETENCY MODEL

3.1 Competencies

Competencies provide a framework for human capital and help organisations focus their employee development in order to gain a competitive edge [8]. Competencies have become a benchmark of organisational effectiveness as organisations realise the intellectual assets their employees are. When an organisation is open about the competencies they require their staff to have, it is easy for employees to understand what they need to work towards to succeed in their careers [9]. Clearly defined competencies will help an organisation to put their business imperatives and objectives into performance requirements for their employees [10]. In order to compile competencies that can be easily understood, it is important to understand what is meant by the term "competence".

Klemp [11] defines competence as a generic knowledge, skill, trait, or motive of a person that is causally related to effective behaviour, and must be manifested in a variety of ways in a number of situations. The term "causally related" means that there is evidence which indicates or suggests that possession of the characteristic (e.g., knowledge, skill, trait, or motive) precedes and leads to effective performance [11]. Parry [12] defines it as "a cluster of related knowledge, attitudes and skills that affect a major part of one's job that can be measured against well-accepted standards and that can be improved with training and development. It is clear from these two definitions that all competencies include attributes / abilities, knowledge and skills.

3.2 History of Competency Modelling

Bartram [13] states that most research defining job performance focused on management positions more than on entry-level jobs. Tett, Guterman, Bleier and Murphy [14] conducted a literature study on 12 different competency models dating back to Flanagan (1951). They found similarities between the models, but also found that there were differences in detail, description, definition, emphasis and level of aggregation.

Borman and Brush [15] propose a structure of four broad dimensions, namely:

- Leadership and supervision;
- Interpersonal relations and communication;
- Technical behaviours and mechanics of management; and
- Useful behaviours and skills (such as job dedication) [13].

Tett et al. [14] developed a taxonomy of 53 competencies clustered under nine general areas. Subject matter experts were consulted to sort 147 behavioural elements in order to derive these 53 competencies. The nine general areas were: traditional functions, task orientation, dependability, open-mindedness, emotional control, communication, developing self and others, occupational acumen, and concerns [13]. Kurz and Bartram [16] describe a job competency framework for managerial and non-managerial positions consisting of 112 competencies which were derived from academic and practice-based competency models. The framework defines the relationships between these competencies, their mapping on to a set of 20 competency dimensions, and their loadings on eight broad competency factors [13].

This paper reviewed the recruitment and development of academic leadership using a leadership competency model.

3.3 Uses of Competency Models

Campion et al., [17] summarised a list of several uses of competency models based on a literature study. Competency models can be useful for selection purposes because competencies of top performers have been identified and new joiners can be measured against a specific profile. Having a competency model in place enables management to identify developmental areas where employees need training. For example, executive development, coaching programs and 360 degree surveys are often built on a competency model foundation [17].

Models that depict levels of competency proficiency, job grade and pay levels can be used as tools around which to structure appraisal instruments to establish promotion criteria [18-20]. Employee information can be easily managed by using competency models to record and archive employee skills and training. By identifying and measuring current competencies a higher retention rate of critical skills can be achieved, enabling the organisation to achieve organisational objectives [21-23]. Developed competency models can assist organisations with change management interventions by providing the ability to align the way in which employees are trained, assessed, selected, promoted and rewarded [24].

3.4 Samples of Available Competency Models

The following two competency models will be discussed to elicit the key elements included in such models:

- Leadership Competency Model (LCM) [25], and
- Leadership Competencies Developed at Indiana University School of Medicine (2007-2009) [26].

The first model was selected because it is generic in nature and does not describe the competencies of a specific industry. The second model, developed by Indiana University School of Medicine was chosen specifically because it is one of few models that speak specifically to academic leadership.

3.4.1 Leadership Competency Model (LCM)

The LCM was developed with the purpose of providing a detailed description of leadership to aid in the development of leaders. It describes five dimensions of leadership competencies, as follows [25]:

- Self-Management;
- Leading Others;
- Task Management;
- Innovation; and
- Social Responsibility.

Each of these dimensions as shown in Table 1 includes several core competencies that are considered valuable skills, abilities, behaviours, attitudes and knowledge areas in which leaders are expected to excel [25].

Table 1: Core competencies and related skills of the Leadership Competency Model (LCM)

Dimension of Competency	Core Competencies	Examples of Related Skills
Self-management	Work Habits	Time management; Goal orientation; Organisation skills; Work ethic; Follow through
	Work Attitudes	Initiative; Effort; Persistence; Energy; Optimism
	Stress Management	Self-control; Stress tolerance; Personal resiliency; Work/ life balance; Resiliency; Adaptability
	Self-Insight	Self-confidence; Self-awareness; Self-reliance; Humility; Suspending judgement
	Learning	Learning strategies; Intellectual curiosity; Continuous learning; Seeking feedback
Leading Others	Communicating	Communicating with co-workers; Active listening; Facilitating discussion; Public speaking; Developing external contacts; Communicating outside the organisation
	Interpersonal Awareness	Psychological knowledge; Social orientation; Social perceptiveness; Service orientation; Nurturing relationship
	Motivating Others	Taking charge; Orienting others; Setting goals for others; Reinforcing success; Developing and building teams
	Developing Others	Knowledge of principles of learning; Interpreting the meaning of information for others; Assessing others; Coaching, developing, instructing
	Influencing	Cooperating; Persuading; Resolving conflicts / negotiating; Empowering; Inspiring; Political savvy
Task Management	Executing Task	Task-relevant knowledge; Delegating; Attention to detail; Coordinating work activities; Providing feedback; Multi-tasking
	Solving Problems	Analytic thinking; Analysing data; Mental focus; Decision making; Designing work systems
	Managing Information and Material Resources	Managing materials and facilities; Managing information resources; Performing administrative activities; Maintaining quality
	Managing Human Resources	Succession planning/ recruiting; Personnel decision quality; Managing personnel policies; Maintaining safety
	Enhancing Performance	Enhancing task knowledge; Eliminating barriers to performance; Benchmarking; Strategic task management
Innovation	Creativity	Generating ideas; Critical thinking; Synthesis/ reorganisation; Creative problem solving
	Enterprising	Identifying problems; Seeking improvement; Gathering information; Independent thinking; Technological savvy
	Integrating Perspectives	Openness to ideas; Research orientation; Collaborating; Engaging in non-work related interests

	Forecasting	Perceiving systems; Evaluating long-term consequences; Visioning; Managing the future
	Managing Change	Sensitivity to situations; Challenging the status quo; Intelligent risk-taking; Reinforcing change
Social Responsibility	Civic Responsibility	Communicating and helping the community; Civic action; Adopting beneficial values for society; Providing a good example; Social action
	Social Knowledge	Social and anthropology knowledge; History and geography knowledge; Foreign language knowledge; Philosophy and theology knowledge; Knowledge of organisational justice; Legal regulations
	Ethical Processes	Open-door policy; Instituting and following fair procedures; Explaining decisions in respectful manner; Ensuring ethical behaviour of subordinates
	Leading Others Ethically	Servant leadership; Valuing diversity; Distributing awards fairly; Responsibility for others; Avoiding exploitative mentality
	Acting with Integrity	Financial ethics; Work-place ethics; Honesty and integrity; Being accountable; Courage of convictions

3.4.2 Leadership Competencies Developed at Indiana University School of Medicine (2007-2009)

The Indiana University School of Medicine (IUSM) faced a number of challenges in the recruitment process including (similar to some of those described above) large and highly variable search committees that lacked clarity regarding expectations for members, selection criteria, and even the search process itself. Further, once on the job, chairs rarely interacted with one another and did not receive structured professional development or feedback to help them assess and increase their effectiveness. Without standardisation in the recruitment, development, and feedback processes, each department often reinvented the wheel for each new search [26].

IUSM resolved these challenges by developing a competency model to help in recruiting and developing the future-oriented, emotionally intelligent, talented leaders necessary for success in the changing and complex environment of the current and future Academic Health Care (AHC). This competency model has six competencies [26]:

- Leadership and team development;
- Performance and talent management;
- Vision and strategic planning;
- Emotional intelligence;
- Communication skills; and
- Dedication to the tripartite mission.

Table 2 lists these competencies as well as a subset of skills associated with each competency

Table 2: Leadership Competencies Developed at Indiana University School of Medicine (2009–2011) [26]

Leadership Competency	Examples of included skills
Leadership and team development	• Engages in succession planning • Creates leadership opportunities for others • Serves as a mentor and/or sponsor • Sets the tone of an equitable and supportive climate for all
Performance and talent management	• Encourages faculty development • Effectively recruits and supports faculty and learners • Provides ongoing feedback • Empowers others
Vision and strategic planning	• Establishes a shared vision • Inspires others toward a common goal • Encourages innovation • Is fiscally responsible
Emotional intelligence	• Is self-reflective • Serves as a role model • Welcomes the views of others • Commits to enhancing diversity

Communication skills	• Articulates a vision • Negotiates for resources and support • Actively listens • Engages others in decision making
Commitment to the tripartite Mission	• Insists that the department advance all three missions • Integrates department goals with stakeholder goals • Advances communities of scholars across mission areas • Adapts to a changing environment

3.5 Evaluation of Models

Before adopting a particular model for use with or without modification, it is important to evaluate it to see how closely it fits the organisation in which it will be used. The evaluation criteria against which each one was measured were:

- External coherence;
- Internal coherence;
- User requirements; and
- Design requirements.

Although these two competency models were developed for different contexts, it is clear that they have many elements in common. For instance, they both identify the skill required for communication, although not under similar rubric.

3.6 Discussion

As noted in the two examples of competency models above, there is a significant departure from the traditional approach of recruiting leaders because of their basis in determining the competencies required for the work at hand and then using them for assessing holders of leadership positions. For this approach to be successful it first and foremost requires the support from the executive leaders. In an academic environment support is particularly helpful when the institution as a whole or a unit in the institution moves from using traditional metrics (e.g., number of funded grants and number of peer-reviewed articles) to a focus on leadership competencies. To ensure the buy-in of all academic staff, current academic leaders as well as executive leaders should be involved in the identification of specific leadership competencies and in the process of determining how they will be used, communicated, and measured.

Centralising and standardising the search and screen process requires dedicated staff effort, which may require the creation of one or more new position(s). This cost should be weighed against the more efficient, streamlined searches that may create cost savings. Further, the cost associated with an internal search specialist is considerably less than regularly consulting search firms. The review of leaders must align with the identified leadership competencies and should include feedback from staff. Aligning the review with the competencies means that, from the point of interview onward, the leader has a clear set of expectations for the areas in which he or she must be competent. Further, annual unit reviews, which address the leadership competencies, may inform not only the professional development goals of individual leaders but also their professional development programming.

4. DEVELOPING ACADEMIC LEADERS

Wolverton and Gmelch [27] defined three dimensions that constitute academic leadership for deans: building a community of scholars, setting direction, and empowering others. They created a survey which asked deans to rate themselves on eight items related to each dimension as shown on Table 3. Overall the means scores for each dimension of leadership were high. All three dimensions were strongly correlated with the dean's perceptions of leadership effectiveness and the deans in the study believed themselves to be effective leaders.

Table 3: Leadership dimensions for deans [27]

Dimension	Items related to the dimension
Building Community	• I show I care about others. • I show concern for the feelings of others. • I involve others in new ideas and projects. • I support effective coordination by working cooperatively with others. • I communicate feelings as well as ideas. • I treat others with respect regardless of position. • I provide opportunities for people to share ideas and information. • I make others feel a real part of the group or organisation.

Setting Direction	• I communicate a clear sense of priorities. • I encourage others to share their ideas of the future. • I engage others to collaborate in defining a vision. • I willingly put myself out front to advance group goals. • I have plans that extend beyond the immediate future. • I am oriented toward actions rather than maintaining the status quo. • I consider how a specific plan of action might be extended to benefit others. • I act on the basis that what I do will have an impact.
Empowering Others	• I make sure people have the resources they need to do a good job. • I reward people fairly for their efforts. • I provide information people need to effectively plan and do their work. • I recognise and acknowledge good performance. • I help people get the knowledge and skills they need to perform effectively. • I express appreciation when people perform well. • I make sure that people know what to expect in return for accomplishing goals. • I share power and influence with others.

"One of the most glaring shortcomings in the leadership area is the scarcity of sound research on the training and development of leaders" [28]. Gardner [29] contends that leadership development is a process that extends over many years. Rather than search for answers in specific training programs, three spheres of influence create the conditions essential to develop academic leaders: (a) conceptual understanding of the unique roles and responsibilities encompassed in academic leadership; (b) the skills necessary to achieve the results through working with faculty, staff, students, and other administrators; and (c) the practice of reflection to learn from past experiences and perfect the art of leadership. These three spheres and their intersections, as illustrated in figure 1, serve as the analytical framework for what is believed is needed to successfully develop effective leaders in the academy" [27].

Figure 1: Spheres of effective academic leadership in the academy [27]

4.1 Conceptual Understanding

Understanding the leadership role of the academic leaders involves understanding the dimensions of leadership that are unique to the academy and unique to the college or division. This can be acquired through mentoring or academic leadership programs. Topics specific to academic administration, such as finance, budgeting and planning are available.

4.2 Skill Development

In addition to a conceptual understanding of leadership, development of specific behaviours and skills, such as communication, conflict resolution, negotiation, resource management and performance evaluation and coaching are also necessary for effective leadership. To some degree these can be acquired in formal training, but on-the-job practice and feedback is important to solidify application of these skills.

4.3 Reflective Practice

Wolverton and Gmelch [27] contend that "leadership development is an inner journey. Self-knowledge, personal awareness and corrective feedback must be part of a dean's leadership journey." They note that dean's isolation in their positions tends to work against the ability to discuss and share with peers, which enables reflection. Opportunities to discuss important challenges in peer groups or with a mentor would help the reflective learning necessary for leadership development.

5. CONCLUSION

Although the definition of leadership in academia is very similar to the one in business setting, many universities have continued to recruit their leadership using the traditional approach based on the seniority

on the academic rank and research profile regardless of whether or not the candidates have proven leadership competencies.

Time and again this approach has led to less than the desired outcomes given the fact that the functions of universities are no longer confined to the three core missions of teaching and learning; research and innovation, and engagement. Universities are being re-defined in many ways: (i) as levers of social mobility; (ii) as engines of local economic growth; and (iii) as founts of technological advances that are changing society. All this makes painfully clear that academics are not always by their training equipped to handle these new expectations.

Recruitment and development of academic leaders using competency-based approach appears to provide effective leadership given that the approach deliberately identifies the capabilities and competencies that are required for the job at hand and if they are found lacking in an incumbent, as systematic training programme is developed to impart them.

Generally, on-the-job experience in different types of academic leadership positions is the typical path toward an academic leadership such as deanship. These experiences form the basis of understanding the leadership role of dean, however they often provide an incomplete picture and may not provide the conceptual understanding and skill development necessary for success in the broader role. Some of best skills a dean can possess are the constant thirst for knowledge, commitment to lifelong learning, and the courage to embrace change in the ever evolving world of higher education. It is believed that the continuation of these innovative, entrepreneurial and managerial efforts will support the faculty and university to meet the changes facing higher education.

However, developing academic leaders takes time and specific steps to understand, practice and refine academic leadership skills. This process requires conceptual understanding, skill development and reflection that can be attained through reading, education, mentoring, skill workshops and peer interaction [27]. Developing leaders in the academy has often been left to chance or the individual mentoring efforts of a few. Given the challenges universities are facing, they should implement a more focused and systematic process for developing future academic leaders. A competency-based approach is the way to go.

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