

EDUCATION AND TRAINING OF ENGINEERS: A CASE STUDY

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Engineering Education and Training play an important role in the technical, economic and social progress of society. A number of factors influence the education and training of engineers, from the nature and form of curricular to needs of employers and the changing patterns of professional employment. Key issues are being raised by changes in technology, in society and by the impact of developments in information technology on industry and commercial development, on the engineering profession, on the educational institutions and on education and training of engineers. The paper considers the education and training of engineers using data and information from the Faculty of Engineering and Technology (FET), University of Botswana as a case study. Historical background is introduced. Student enrolment in terms of gender and foreign students are presented. Also presented are the academic programs and staff structures. The goals of the Faculty have been highlighted and the strategies to be applied to achieve these goals have been recommended. The paper could be of interest to staff of FET and UB, Engineering Institutions in Africa and also to the Botswana Ministry of Finance and Manpower Development.

1 INTRODUCTION

1.1 The Socio-Economic Context

Botswana has a young and rapidly growing population. The current population stands at 1.5 million. In 1991 about 42% of population was under 15 years. According to projections by the Central Statistics Office (CSO), between 37 000 and 50 000 people will be added to working age group (15-64 years) each year between 1991-2017. The provision of 10 years universal basic education up to Junior Certificate (JC) will however delay the entry of the majority of this group into the labour market. Beyond this level a maximum of 50% of JC leavers proceed to senior secondary education. For the remaining 50% the choice is between pursuing some kind of skills training or joining the labour market.

Vocational training system (excluding the private training institutions) can accommodate only about 4 000 and these places are competed for by both JC leavers and form 5 leavers. Technician training opportunities are equally limited. Access to further technical and vocational education and training beyond JC level therefore still remains a major challenge [1]

1.2 The Need for Skills Acquisition

Botswana's economy continues to undergo a rapid transition from predominantly traditional to a more modern economy in which skill acquisition will be the main vehicle for employment. Future economic growth will rely on the ability of the nation's workforce to apply advanced production technology and respond to changing demands of industry. This applies to both the formal and the informal sectors if they are to participate effectively in the process of development. Nevertheless, the capability of the workforce depends on their skills. Presently, there

are many skills that are imported and many of these are basic. This is because of the lack of such skills locally.

On account of the above socio-economic factors, it is necessary to develop skills not only for new entrants to the labour force but also upgrade the skills of those already in the labour force. The Faculty of Engineering and Technology (FET) through its programs and the organization of short courses assist in the development of the needed skills.

2 FACULTY OF ENGINEERING AND TECHNOLOGY, AN OVERVIEW

2.1 Historical Background of the Faculty of Engineering and Technology

The Faculty of Engineering and Technology evolved out of an institution that has grown over the years due to the nature of the work it offered at different times. In 1979, two-year courses leading to the award of internationally recognized City and Guilds of London Institute Certificates were introduced at both craft and technician levels. The center then became known as the Botswana Polytechnic with three Departments of Civil, Electrical and Mechanical Engineering. As time passed by, more and more courses at technician level were introduced in response to the demand for artisans in the country's industries. In the late 1980's the diploma courses were introduced in the three Engineering Departments. Also the Department of Teacher Education was established to train Design and Technology Teachers for Secondary Schools. In 1989 the degree programs were launched in all the four Departments. The first cohort of degree students completed their programs during the 1994/95 academic year and for the first time, twenty-four engineering and seven of design and technology degree graduates were among the University of

Botswana graduates of October 1995[2]. The Botswana Polytechnic was finally incorporated into the University of Botswana as the Faculty of Engineering and Technology on 1st January 1996.

2.2 Academic Programs

Four departments constitute the Faculty of Engineering and Technology; Civil Engineering, Electrical/Electronic Engineering, Mechanical Engineering and Technology and Educational Studies Departments. All the departments offer certificate and diploma programmes in relevant disciplines. The programs are[3]:

2.2.1 Civil Engineering Department

- 2 - year Diploma in Water and Environmental Engineering
- 2 - year Diploma in Land Surveying
- 3 - year Diploma in Mining Engineering
- 2 - year Higher Diploma in Water and Environmental Engineering
- 51/2 - year Degree in Building Engineering
- 51/2 - year Degree in Civil Engineering

2.2.2 Electrical/Electronic Engineering Department

- 2 - year Diploma in Electrical/Electronic Engineering
- 2 - year Higher Diploma in Electrical/Electronic Engineering
- 51/2 - year Degree in Electrical/Electronic Engineering

2.2.3 Mechanical Engineering Department

- 2 - year Diploma in Mechanical Engineering
- 2 - year Higher Diploma in Mechanical Engineering
- 51/2 year Degree in Mechanical Engineering

2.2.4 Technology and Educational Studies Department

- 5 - year Degree of Education (Design and Technology)

Except for Technology and Educational Studies Department, all the other departments offer a two - year program, leading to the award of certificates in the respective subject disciplines.

2.3 Admission Requirements

The Faculty offers programs in the four departments at Certificate, diploma and degree level. The admission requirements for the various levels are:

2.3.1. Certificate programs

A General Certificate in Education (GCE) Certificate or equivalent with passes in Mathematics, Physics or Physical Science or Combined Science.

Or

A Junior Certificate plus a relevant Craft Certificate with Credits in Mathematics and Science.

Students with a relevant City and Guilds Certificate or equivalent may be admitted to the second year of the Technician Certificate Program.

2.3.2. Diploma programs

A Third Division in the Cambridge Overseas School Certificate (COSC) or its equivalent, with Credits in Mathematics and at least one Science subject as specified in the Special Departmental Regulations (normally the Science subject can be either Physics or Physical Science). Alternative entry qualifications may be considered at the discretion of the Departmental Board, and it may be necessary to conduct interviews and/or aptitude tests in the process.

2.3.3. Higher Diploma programs

A Diploma or its equivalent, as specified in the Special Departmental Regulations. In addition, candidates must have at least one year relevant industrial/work experience, or as specified in the Special Departmental Regulations.

2.3.4 Degree programs

A successful completion of year 1 of the B.Sc. general degree, or should possess the A levels of COSC these would then enroll onto the Engineering Foundation Course for a duration of 18 weeks before they are admitted to the year 2 of the Bachelor of Engineering Program. Those who obtain a minimum of at least credit in Diploma program enter directly into year 2 and are exempted from the Engineering Foundation Course. The Degree programs are for a period of 5 ½ years. The Diploma programs are for a period of two years, except for diploma in mining engineering, which is for a period of 3 years.

The certificate programs are two- year programs. One semester out of the 5½ years degree programme is used to introduce year one leavers to workshop practice.

2.4 Practical Training

It is the practice of the Faculty to organize attachment to industries and areas of practical

interest to assist students in their practical training. Priority is given to those engineering concerns in which maintenance and workshop practice have a major role as these offer practical exposure that may not be available in the Faculty. Students are required to submit reports on their job experience during these attachments to the Departments for grading. The attachments for the degree students take place in semester 6 and semester 9.

2.5 Projects And Examination Papers

Every effort is made to propose final year degree projects that are of practical importance to industry and to Botswana. In semester 8, students carry out minor projects. This arrangement enables the students to put up an improved and better presentation of their projects in the final year. The examination papers and projects are reviewed internally and by external examiners, to ensure that a high standard is maintained.

2.6 Staff Structure

Because of the different levels of programmes offered by the Faculty, the Faculty has a unique staff structure made up of academic staff, tutors and instructors. Each cadre complements the other in ensuring that students registered in the Faculty programmes receive adequate training and education in the practice of science and technology. The three cadres are [4]:

Category 1: Staff (Academic) designated as;
Professors, Associate Professors,
Senior Lecturers, Lecturers and
Staff Development Fellows (SDF)

Category 2: Staff (Tutors) designated as;
Chief Tutors, Principal Tutors,
Senior Tutors, Tutors, Assistant
Tutors

Category 3: Staff (Instructors) designated as;
Chief Instructors, Principal
Instructors, Senior Instructors and
Instructors

Category 1 Staff (Academic): those who would have a minimum of MSc/M.Eng. degree and higher. They will normally be required to teach at degree, diploma and certificate programmes, supervise projects and carry out research and consultancy.

Category 2 Staff (Tutors): those who would normally have either a first degree or a higher diploma (HND, HNC etc) qualification as well as experience in practical skills. They would normally be required to teach in the diploma and certificate programs, and

take part in courses (practicals/tutorials) in the degree programs in collaboration with category 1 staff.

Category 3 staff (Instructors): those who would normally have academic qualification at diploma or technician level and are assigned to Faculty Workshops.

Category 2 and 3 staff structure have been designed to invite experienced engineers and technicians, who might not possess high academic qualification, to impart their practical experience and knowledge to the Faculty of Engineering and Technology Students. This arrangement is made to ensure that FET students obtain the necessary theoretical and practical skills

2.7. Students and Staff Population

2.7.1. The student population by programs [5]:

Certificate	297
Diploma	305
Degree	213
Total	815,

2.7.2. Student Population by Departments:

Civil Engineering	195
Electrical/Electronic Engineering	254
Mining Engineering	18
Mechanical Engineering	254
Technology & Educational Studies	94
Total	815

Table 1: The breakdown according to foreign students' population and gender

Student Population at UB*	Number	Percentage
Total population	8302	
FET** students	815	0.9
Foreign students	148	0.18
Female students	111	0.136

* University of Botswana

** Faculty of Engineering and Technology

Approximately 60% of the student population graduate. The student population figures have been approximately constant for a number of years due to inadequate laboratory and classroom space. It is hoped that when new physical facilities are completed the numbers will be increased.

Table 2: Training and Localization of staff

DEPARTMENT AT FET	Civil	Electrical	Mech.	TESD [*]
Establishment	19	20	18	11
Expatriates	13	17	10	5
Citizens at post	4	3	7	3
Citizens on Training	1	1	1	2
Total citizen	5	4	8	5
Female citizen	0	0	0	0
Male citizen	5	4	8	5
SDF (training)	0	2	0	0
SDF ^{**} at post	3	1	2	3
Total staff	18	21	18	10

FET has four Departments:

Civil, Mechanical, Electrical Engineering; and TESD

* Technology and Educational Studies
 ** Staff Development Fellow

3 MISSION STATEMENT AND GOALS

The Faculty of Engineering and Technology intends to develop into a national resource that will support the development of Botswana and in particular, its economic diversification responsive to the needs of Government, industry and society at large, the Faculty of Engineering and Technology will [6]:

- Provide up - to - date technical and engineering training, including the training of teachers of Technology; that prepares students to meet the responsibilities of the workplace
- Carry out appropriate research, and
- Act as a centre for advisory services in support of the engineering and technical needs.

Beyond this, the Faculty of engineering and Technology will seek to become a centre of excellence that will provide support and assume a strong role in the development of the region. In working towards this mission, the Faculty of Engineering and Technology will strive for standards of excellence in all its endeavours.

Three main **GOALS** have been identified:

- **Satisfying Stakeholders Needs.** The Faculty of Engineering and Technology must be accountable for its activities, both as an essential part of its quality management and as a fundamental requirement for identifying the specific activities it should engage in. This is only possible if there is dialogue with, and responsive to, the needs of stakeholders.

- **Improving efficiency.** The operation of the Faculty of Engineering and Technology must strive to maximise the utilisation of its resources, achieve cost effectiveness and ensure that its stated goals are implemented.

- **Developing Facilities.** The Faculty of Engineering and Technology must provide an environment within which its mission can realistically be achieved. This can only be done by a commitment to develop and maintain high quality facilities.

To achieve these goals, planned strategies must be developed. The following are recommended, bearing in mind the general approach to engineering education and training.

4. STRATEGY

4.1 Industry – Institution Linkage

The linkage between the industry and the institution can provide a great impetus in developing the desired manpower for industrial activities. This linkage exposes the Faculty to industrial problems and motivates them to develop expertise for consultancy. Likewise, it helps in keeping the field engineers abreast of new academic programmes and advancements for application in their shop floor practice. Industry – institution linkages, in general provides proper forum for the cross fertilization of theoretical education at institutions with actual practical/shop floor experience in industry, in design, production, operation, maintenance, etc. so that industrial training becomes integrated with the total process of engineering education at degree and diploma levels. The advantages occurring from such linkages are multidimensional in nature. It can expose a student to the ways of industrial practice so as to recognise his roles and responsibilities as professional engineer/technician besides providing first hand and ready made experience of the industrial problems and the solutions associated with it. This part, the institution can definitely improve upon, but physical facilities which are often plagued with problems like obsolescence, inadequacy, and modernization. All in all, the industries contribute significantly towards improving the quality of engineering education by bringing in a sense of realism and practicality to the academic programmes and the institutions on the other and, can provide the technological back-up expertise and facilities, to accelerate the pace of industrial development [7].

On the understanding of benefits to be drawn from Industry – Institution linkage, FET has established a collaborative relationship with industry and other stakeholders. This arrangement makes it possible for FET engineering students to receive industrial

training and exposure in industries and in NGO's and other Government parastatals in Botswana. The students spend a total of two semesters (one academic year) in Industry. At the end of years 2 and 3 the engineering students spend a total of 40 weeks in industry on industrial training.

The collaboration permits the Faculty to invite stakeholders from industry, private sector and Government Parastatals to the Faculty's annual workshop on engineering education. At the workshop, issues that impact on the engineering and training are discussed and recommendations are made for consideration by the Faculty. The stakeholders also have input in the review of syllabi and curriculum development which are developed to meet the changing technological world.

4.2 Sponsorship

The established relationship between the Faculty and stakeholders is a loose one. There is no definite contributions in terms of donations, equipment or financial support. As a result sponsorship of students in the Faculty is mainly by the Botswana Government. Unlike the degree students in other faculties, engineering students enjoy full bursaries from Government. (Currently there are approximately 815 students in the Faculty of which about 148 are foreign students and the rest are citizens of Botswana). Government sponsors more than 90% of the citizen students while the remaining small percentage – 10% are privately sponsored.

With stronger ties, stakeholders could be obliged to contribute meaningfully towards the education and training of engineers in Botswana. Education and Training of Engineers is highly costly. The practice in some countries by which stakeholders and companies that contribute to the education and training of engineers are given proportionate tax - relieve is recommended.

4.3 Computer center / Internet Facilities

Computer courses and training are offered to all engineering students at all levels. The Faculty has established students' computer centre and CAD centre. The computer centre is linked to the internet. This gives, apart from computer studies, the students access to e-mail and internet facilities. The centre operates daily from 8:00 till midnight under the supervision of computer tutors, who also assist the students in their computer studies. Information Technology is developing at an alarming rate. Students should be educated on the efficient and productive use of the inter-net facilities.

4.4 Programs

As mentioned before, there are only four departments in the Faculty (Mechanical, Electrical, Civil and Technology and Educational Studies). These are the traditional departments inherited from the former Polytechnic. Obviously the programs offered are too few to meet the demands of a new emerging industry. The scenario is that there are many graduates now with qualifications from the four departments and as such competition to secure employment in their areas of specialization is high, while there are other engineering courses which are greatly needed but are not offered in the faculty. It is therefore recommended that the faculty steps-up the introduction of new programs in response to the needs of industry. The introduction of semesterization and modularization could make it possible for more options of courses to be introduced into the programs.

4.4 Planning Committee

The Faculty has three main goals: satisfying stakeholders needs, improving efficiency and developing facilities. A Planning Committee should be set up to plan the implementation of new programmes and to monitor and advise the Faculty on the progress made towards the achievement of the goals and objectives of the Faculty.

5 RECOMMENDATIONS

To improve the provision of education and training of Engineers at FET, the following are also recommended:

- i. **Recruitment of Professional engineers**
Professional Engineers should be recruited to teach a few hours per week on part-time basis so as to impart knowledge of latest technology in industry to students.
- ii **Industrial attachment for new and old staff**
Serving members of staff should be given approval on request for a short study leave of about three months to enable them to up date their knowledge in modern technology in industry. This arrangement should be formalized with industries and should involve all departments.
- iii **Formal Establishment of Departmental and Faculty Boards**
Currently all departments have Advisory Boards which are supposed to meet annually to discuss issues that relate to the improvement of the curriculum. However, the current arrangement is a loose one and it is recommended that the establishment of advisory boards for departments be

formalized with proper terms of reference and scheduled annual meetings.

The Faculty Advisory Board is yet to be established. However the important role of the board cannot be overemphasized. Once it is set up and recognized as a forum that advises on the improvement of engineering education and training, no doubt it will serve as a legitimate and useful link between the Faculty and industry, thereby making the training provided by the Faculty relevant to industry in Botswana.

iv Improvement of Facilities

Because the Faculty still operates from the site inherited from the former Polytechnic, the facilities are far too small, and inadequate for the introduction of new programs. This makes it difficult for the Faculty to reach its goals. Improvement of facilities is a must, if the Faculty is to fully fulfil its mission.

v Research Funding

Currently the University provides limited research funds through its annual budget. This is proving to be far too inadequate to support meaningful research. It is recommended that industry should be encouraged to support research through funding. Perhaps the small industrial base currently prevailing in the country is the major impediment, but it is the view of the authors that this small industry base should show interest in supporting engineering training by making some contribution towards research funding. As an incentive, proportionate tax relieve should be credited to industries and companies that contribute to fund research and training of undergraduate and graduate engineering students. In some countries such as Germany and the US, about 70 per cent of research funding to engineering institutions are provided for by industry. The industries also sponsor graduate students and encourage graduate programs.

vi Curriculum Review

The current practice is to review the curriculum of a program after its full cycle, that is, after the first batch of its intake has completed the program. While this is good, it is felt that continual review such as introduction of new topics relevant to industry even before the program has had a full cycle will go along way in making the program and its graduates relevant to industry. Semesterization and modularization of programs in the faculty will provide flexibility in the education and training of engineers in FET.

vii Provision of Short Courses to Industry

The Faculty offers short courses to industry. However, this activity is still on a small scale because the University is still rigid about the issue of certificate for short courses. The current practice is

that any course that culminates with a University award should go through the approval process of the University. This practice is time consuming and therefore discouraging to both the Faculty and industry. It is therefore recommended that the University should encourage the provision of short courses to industry by devolving the responsibility of issuing of awards at the end of the short courses to the faculty. Industries should also be encouraged to provide periodic short courses on modern technology to FET staff.

viii Consultancy

Consultancy work should be encouraged and developed in the faculty. Departments should solicit consultancy work from industries and companies. In this manner, the faculty would be assisting industries and companies to solve some of the pending problems. The faculty consultants will in this process be gaining practical experience and knowledge. The faculty will be advertising itself to the public and will also be better off financially.

ix FET Alumni

A FET Alumni Association is being advocated. The main purpose is to,

- Maintain contacts among graduates and staff of the faculty
- Keep the graduates informed of various programs and activities of the faculty
- Involve the graduates in various programs / activities for individual and national development
- To act as a forum for exchange of ideas and experience and to get feed back on their performance at work
- To organize activities to raise funds for the development of the faculty.

6 CONCLUSION

The Faculty of Engineering and Technology of the University of Botswana is a new Faculty. Consultancy work and applied research have not been firmly established. However, to maintain good quality engineering education and training, a number of steps have been taken, these include a one academic year of attachment to industry, a one semester workshop practice and the introduction of computer courses at all levels of engineering programmes. The establishment of students computer centre and the CAD centre enables the students to improve their knowledge in the use of computers and its application to solving engineering problems.

FET graduates are readily employed in government, parastatals, and the private sector an indicatium of stake- holders satisfaction with FET products.

However, FET graduates like graduates of other Faculties are also facing the problem of not securing employment immediately after completion of their studies. The job market in the country is now tight such that it takes some time before one is employed. The situation is however, now improving with the economy of the country picking up. It would be appropriate for the Faculty to establish FET-Industrial advisory board at which forum job opportunities could be made available to graduating students and possibly conduct interviews for possible employment immediately after successful completion of studies. At the same time views should be exchanged on how to improve on the quality of engineering education. The forum should be an annual event. Stronger links with industry is advocated. The need for research funding has been presented and an improvement of the physical facilities of the faculty to facilitate the quality of engineering education and training has been highlighted.

The paper could be useful to young Engineering Institutions in Africa and also to the Ministry of Finance and Manpower Development of Botswana.

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