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Aligning an Engineering Education Program to the Washington Accord Requirements: Example of the University of Botswana*

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The accreditation systems of engineering education programs governed by the Washington Accord have evolved in order to respond to modern technological and scientific development. The principal purpose of the paper is to indicate that the process re-engineering model commonly employed in business environments can also be used in an educational system. In particular, the paper describes the process of re-engineering used for the transformation of the BEng (Mech) program in order to align it with the accreditation requirements. The study adopts a Business Re-engineering Process (BRP) in which engineering education is considered as a process. A modified McKinsey's re-engineering model was chosen as a tool to re-engineer the educational system. The model involves five broad phases, namely, identification, review & analysis, re-design, test & implementation and continuous improvement. The paper concentrates on the first two phases. The existing curriculum is mapped according to the graduate attributes, competency profiles and the Exit Level Outcomes of the Engineering Council of South Africa (ECSA). From the list of identified deficiencies it can be concluded that the major shortcoming of the program is not its content but its delivery. It is recommended that innovative flexible delivery methods should be used as teaching styles.

Keywords: accreditation; re-engineering; mechanical engineering program

1. Introduction

Engineering practice continues to evolve in response to modern technological and scientific development. However, in many countries changes in engineering education have not been rapid in the last five to six decades [1]. The circumstances facing practicing engineers today are considerably different from those of the past, due to the new demands and new challenges in the diverse, profound, and incessant changes, which confront mankind in the 21st Century. Moreover, the circumstances of the future will be even more different and challenging [2, 3]. Therefore the quality of future engineers critically depends on the quality of engineering education, which is itself dependent upon developments in engineering curricula [2].

Engineers in the past were mainly concerned with the technical aspects of engineering, commonly known as hard-engineering skills. In particular, engineering education was successful in transmitting the technical knowledge to engineering students. As the environment in which engineers operate is constantly changing, educators of new cohorts of engineers should change their teaching styles and adopt new approaches in program design and delivery. Rugarcia et al. [3] succinctly stated that:

> *Until about 30 years ago, most engineering professors had either worked in industry or consulted extensively, and the facts and methods that constituted the knowledge base of the engineering curriculum were by and large those that the students would need in their careers. The primary values of engineering practice at the time were functionality and profit. A good process was one that did what it was supposed to do in as profitable a manner as possible. Both the engineering curriculum and the faculty reinforced these values.*

However, as mentioned before, the world changed and the role of engineers has changed as well. The modern society faces enormous challenges including international competition, the global environment, and an increasingly diverse and rapidly growing population. In this context, engineers are involved in the implementation, application, operation, design, development and management of pro-

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jects and processes. The "engineer of the future" should be able to apply scientific analysis and holistic synthesis to develop sustainable solutions that integrate social, environmental, cultural, and economic aspects of complex and globalised systems [4].

The requirements of the 21st-century professional engineering practice are considerable and therefore engineers must be technically competent, globally sophisticated, culturally aware, innovative, entrepreneurial and nimble, flexible, and mobile. In particular, globalization demands that engineering practice to be international in scope. This has led to the need for credentialing of graduate engineers who want to practice in a global context. In this sense, the engineering education system for the future should be broad-based and the engineering programs should be able to adapt easily to the continuously changing technology and environment.

In response to the new globalisation trend and needs, the accreditation systems of engineering education programs have evolved in order to provide mutual recognition of the different engineering Licences across national borders—both for educational equivalency and for practice mobility.

The Accreditation systems are traditionally viewed as a measure of quality of the program [5]. Also an accreditation system is necessary in countries where major changes are occurring in the education pattern. It is also important in developing countries where it is necessary to improve the quality of engineering graduates in order to build an indigenous technological base upon which the local economic growth will depend on [6].

Different international agreements to provide mutual recognition of the national accreditation systems have been developed. One of the first, and probably the most adopted, is the Washington Accord (WA), which was developed among the engineering boards of some English speaking countries: Australia, New Zealand, Canada, the United States, Ireland, and the United Kingdom. Since then, some other countries have signed the accord. These countries have a lot of differences in their national accreditation systems, but have agreed that the resulting engineering graduate capabilities and knowledge are essentially equivalent.

In order to enhance the quality of engineering education in Botswana and also acquire international recognition, the Faculty of Engineering and Technology (FET) at the University of Botswana (UB) is working to comply with the requirements of the Engineering Council of South Africa (ECSA) for the accreditation of the Bachelors degree program in Mechanical Engineering. ECSA is currently the only African engineering board which has already signed the Washington Accord. To satisfy all the ECSA requirements the FET UB needs to rethink and re-engineer its educational process.

Re-engineering of an engineering program can cover multiple issues which, although closely related, can also be assessed independently. The main concern is normally the curriculum but re-engineering (or re-design) can include development of new academic programs, courses, course formats, content and/or the sequence of contents. An extensive work in respect of engineering curricula reform was carried out at several universities in the USA [7].

The paper intends to show that the re-engineering model commonly employed in business environments can as well be used in an educational system. In order to achieve these aims, a Re-Engineering process methodology has been adopted to transform the BEng (Mech) program so as to align it with the accreditation requirements. During the analysis step of the process, the current FET UB program on offer was compared with the ECSA and WA accreditation requirements. Some gaps were identified in the program and the paper proffers suggestions on how to fill those gaps.

2. Washington accord and ECSA accreditation system

2.1 Washington accord

The Washington accord was created in 1989 as an international accreditation agreement among bodies responsible for accrediting engineering degree programs. The accord promotes the equivalency of programs accredited by those bodies and recommends mutual recognition of graduates of programs accredited by any of the signatories as having met the academic requirements for entry to engineering practice in member countries [8]. There are currently 13 signatory organizations (as shown in Table 1) and 6 others hold provisional status. These organizations represent Germany, India, Pakistan, Russia, Sri Lanka and Turkey.

The Washington accord's program requirements are designed on the Outcomes Based Education (OBE) principles. Outcomes Based Education involves a paradigm shift in curriculum design, mode of instructional delivery, assessment and reporting practices in education to reflect the achievement of high order learning rather than the accumulation of specific number of course credits [9]. In particular, OBE specifies the "outcomes" that students should acquire and demonstrate upon successful graduation from an accredited program [10, 11]. It focuses on educational experiences, skills and competencies that could develop the expected graduate (e.g. design competencies, engineering knowledge, communication skills, leadership &

Table 1. Current signatory organizations of the Washington Accord

Country	Signatory organizations	Date joined
USA	Accreditation Board for Engineering and Technology	1989
Canada	Canadian Council of Professional Engineers	1989
UK	Engineering Council United Kingdom	1989
Australia	Institution of Engineers Australia	1989
Ireland	Institution of Engineers	1989
New Zealand	Institution of Professional Engineers New Zealand	1989
Hong Kong China	Hong Kong Institution of Engineers	1995
South Africa	Engineering Council of South Africa	1999
Japan	Japan Accreditation Board for Engineering Education	2005
Singapore	Institution of Engineers Singapore	2006
Chinese Taipei	Chinese Taipei: Institute of Engineering Education Taiwan	2007
Korea	Accreditation Board for Engineering Education of Korea	2007
Malaysia	Board of Engineers Malaysia	2009

teamwork, management skills, social awareness, environmental sustainability and lifelong learning).

The Washington Accord specifies the graduate attributes and the competency profile that all engineering students should possess at the end of their educational career to qualify for registration as a professional engineer. The attributes show that engineering programs must not only teach the fundamentals of engineering theory, experimentation, and practice, but should also prepare students for a broad range of careers and life-long learning [12].

2.1.1 Graduate attributes

The graduate attributes are a set of individually assessable outcomes that are indicative of the graduate's potential and competence to practise at the appropriate level. The graduate attributes are designed to assist in the development of criteria and guidelines to be used for assessing readiness and suitability of a program seeking accreditation status (Table 2).

The graduate attributes are stated generically and are applicable to all engineering disciplines. Within a disciplinary context, individual statements may be amplified and emphasised but they must not alter attributes in substance or ignore individual attribute elements.

2.1.2 Competency profile guidelines

A professionally competent person should have the attributes necessary to perform the activities within the profession or occupation to the standards expected in independent employment or practice. Individual elements are formulated around what a competent person should acquire similar to the graduate attributes described in the previous section. As in the case of the graduate attributes, the professional competency profiles shown in Table 3 are not prescriptive but rather reflect the essential elements that would be present in competency standards [13].

2.1.3 Curriculum structural requirements

As mentioned before, the Washington Accord is not prescriptive in terms of the curriculum structure but only provides guidelines related to the knowledge profile. In particular, Washington Accord's accre-

Table 2. Washington accord Graduate Attributes [13]

No	Graduate Attributes	No	Graduate Attributes
1	Engineering Knowledge	7	Environment and Sustainability
2	Problem Analysis	8	Ethics
3	Design/ development of solutions	9	Individual and Team work
4	Investigation	10	Communication
5	Modern Tool Usage	11	Project Management and Finance
6	The Engineer and Society	12	Lifelong learning

Table 3. Competency profiles [13]

No	Competency profiles	No	Competency profiles
1	Comprehend and apply universal knowledge	8	Ethics
2	Comprehend and apply local knowledge	9	Manage engineering activities
3	Problem analysis	10	Communication
4	Design and development of solutions	11	Lifelong learning
5	Evaluation	12	Judgement
6	Protection of society	13	Responsibility for decisions
7	Legal and regulatory		

dited programs would provide sufficient evidence of knowledge in:

- Basic Science and Mathematics
- Engineering (basic and specialist) and applied science
- Complementary studies
- Practice, i.e. that summarizes all the acquired knowledge

Each WA member organisation has to translate and firm up these indicative requirements into more detailed explicit accreditation rules and guidelines which should be contextualised for the particular country and operating environments.

2.2 ECSA accreditation system

The Engineering Council of South Africa (ECSA) is the statutory body for the engineering profession in the Republic of South Africa. ECSA promotes high quality education and training of professional engineers and facilitates recognition of good practice in the engineering profession [14]. ECSA is mandated to conduct accreditation visits to educational institutions to assess engineering qualifications for recognition by the Council for purposes of registering graduates from those institutions/programs. A program is accredited when its graduates have satisfactorily met the educational requirements in all categories as stipulated by ECSA. Accreditation recognises individual programs and not academic departments or universities.

The accreditation process for South African engineering programs was extensively revised in the late 1990s and in particular outcomes based criteria were introduced in 2000 in response to the Washington Accord requirements. Pursuant to this review, ECSA adopted common accreditation criteria, policy and processes for all programs applying for accreditation. ECSA requirements for engineering programs are not limited only to the curriculum structure but include also program aims, objectives and outcomes, quality of teaching and learning (e.g. academic staff, students, facilities), resources and sustainability of the program.

A summary of the four key criteria defined by ECSA are presented below [14].

Criterion 1: Credits, Knowledge Profile and Coherent Design

The study leading to the qualification is to be a four-year full-time equivalent program with a minimum of 560 SAQA credits as shown in Table 4 by knowledge areas. South African Qualifications Authority (SAQA) is the body responsible for overseeing the development and implementation of the National Qualifications Framework [15]. One credit is the value assigned by the Authority to ten notional hours of learning (including both instruction and preparation by the student).

Table 4. ECSA Program Structure Requirements

Knowledge area	Min Credits	Percentage
Mathematical Sciences	56	10%
Basic Sciences	56	10%
Engineering Sciences	168	30%
Design and Synthesis	67	12%
Computing and IT	17	3%
Complementary studies	56	10%
Discretionary	140	25%
Total Credits	560	100%

Criterion 2: Assessment of Exit Level Outcomes

Ten Exit level outcomes (ELO) have been defined by ECSA. They are stated generically and may be assessed in various engineering disciplinary or cross-disciplinary contexts in a provider-based or simulated environment. In particular, these ELO, based on the OBE approach, have been defined in terms of the attributes of graduates and the competency profile guidelines in the Washington Accord. Table 5 presents a list of the ELOs and a comparison with the graduate attributes and competency profiles.

Criterion 3: Quality of Teaching and Learning

In order for a program to be accredited, it has to be structured to provide an effective teaching and learning process to enhance the fulfilment of the ELOs defined in the Criterion 2 above. The learning process has to be structured to encourage independent learning attitudes and abilities. Also an appropriate mix and balance between different teaching and learning methods is required to foster active participation of students in the teaching and learning process. Moreover, it is compulsory to establish a methodology to strictly evaluate the progress of learning and, where necessary, to provide academic support for students through structured and monitored interventions.

The students' admission standard has to be commensurate with the program's academic requirements. The number of students admitted has to be based on the capacity of the program to offer good quality education and to meet professional expectations.

Criterion 4: Resourcing and Sustainability of the Program.

This criterion can be subdivided into two main areas:

- Academic staff: academic staff responsible for delivering an engineering program has to be professionally and technically competent and

Table 5. Comparison of exit level outcomes, graduate attributes and competency profiles

ECSA Exit level outcomes	Graduate attributes	Competency profiles
Problem solving	Problem Analysis	Problem Analysis
Application of scientific and engineering knowledge	Engineering Knowledge	Comprehend and apply universal knowledge
		Comprehend and apply local knowledge
Engineering Design	Design/ development of Solutions	Design and development of solutions
Investigations, experiments and data analysis	Investigation	Evaluation
Engineering methods, skills and tools, including Information Technology	Modern Tool Usage	Engineering practice
Professional and technical communication	Communication	Communication
Impact of Engineering activity	Environment and Sustainability The Engineer and Society Project Management and Finance	Protection of society Manage engineering activities Legal and regulatory
Individual, team and multidisciplinary working	Individual and Team work	Individual and Team work
Independent learning ability	Lifelong learning	Lifelong learning
Engineering Professionalism	Ethics	Ethics Judgement Responsibility for decisions

actively involved in research, development and scholarly activities.

- Facility & Resources: an adequate plan for the allocation of funds and necessary resources is required. It is important that the budgetary allocations for the program are both adequate and effectively utilised.

3. Engineering programs at the University of Botswana

The University of Botswana (UB) is currently the only tertiary institution in Botswana offering degree programs in Engineering. The University was established in 1982 and had no engineering faculty until the erstwhile Botswana Polytechnic was incorporated as the Faculty of Engineering and Technology (FET) into UB in 1996. In 2002, UB undertook a major reorganization of its academic programs by changing from a subject-based system to a semester system with course credits and grade point averages [12]. To enhance its international recognition, FET is ‘‘re-engineering’’ its programs to be aligned with the Washington Accord and the ECSA accreditation requirements.

Several tools and techniques associated with the traditional business practices (such as change management, total quality management, downsizing, restructuring, benchmarking, design and systems development and process mapping) could be adopted to improve the higher educational systems [16]. In particular, in order to be competitive institutions have to invest heavily in the re-engineering of their core business, which is education and training [17]. Adoption of the Business Process Re-engineering (BPR) approach improves effectiveness in service delivery which is in sync with their customers' needs [18].

3.1 The methodology adopted to re-engineer the educational system

Re-engineering activities can be considered at any level of an organizational process. Process re-engineering covers the examination, study, capture, and modification of the internal mechanisms or functionality of an existing process. It is carried out in order to reconstitute it in a new form and with new functional and non-functional features, often to take advantage of new or desired organizational capabilities. However, the inherent purpose of the process that is being re-engineered should not be changed. Hammer aptly defined Re-engineering as ‘‘the fundamental rethinking and radical redesign of business processes to achieve dramatic improvements in critical, contemporary measures of performance such as cost, quality, service and speed'' [19]. Also Davenport stated that a ‘‘process is a structured, measured set of activities designed to produce a specified output for a particular customer or market'' [20].

The re-engineering of educational programs can be carried out by using different methodologies such as system approach [21] or integrated system thinking [7]. They can also be based on different educational concepts, for example, cognitive learning [22], project oriented learning [22, 23] or service learning [24].

Some authors have considered the adoption of different new management philosophies, tools and techniques such as Total Quality Management

(TQM), Deming's system of profound knowledge, Business Process Re-engineering (BPR), Lean Thinking and Six Sigma to improve the university systems and service delivery in a systematic way [25–29]. In particular, the BPR approach has been used to rethink the higher education systems with the aim of improving the effectiveness of service delivery and to reduce costs [18, 29, 30]. Business Process Re-engineering describes an organization considering different aspects, such as the organizational structure, processes, staff and resources and how they interact. The BPR approach is useful in the contexts where there is need to improve both the internal and external performance in an intensely competitive market as the educational system. Therefore the BPR approach can be easily applied to an educational system. In the BPR model, the university/college can be considered as the organization delivering a set of processes, which all together constitute the educational system. Some of the desired advantages of BPR are [31]:

- speed—time to complete key processes,
- flexibility—adaptable processes and structures,
- quality—in terms of service delivery,
- productivity—effectiveness and efficiency of service delivery and
- innovation—imaginative positive change to existing processes.

The method chosen to re-engineer the educational system at FET is based on the re-engineering process cycle models developed by Hammer [19] and Zigiaris [32] and later improved by McKinsey [33]. The major components of a Business Process Re-engineering Life Cycle are presented in Fig. 1.

There are five major phases in the re-engineering model as described by Zigiaris [32].

Identify processes: In this phase, it is important to identify ECSA requirements that BEng (Mech) program at FET UB should implement. Moreover it is necessary to establish a strong commitment at all the different levels of the University, Faculty/College and Departments. In particular, all the academic staff should be aware of the aim of the Re-engineering process.

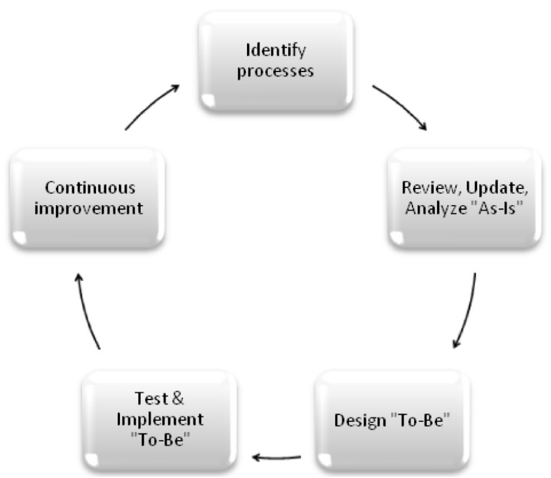

Fig. 1. Re-engineering process cycle model [21]

Review, Update, Analyse "As Is": This phase aims to diagnose and identify problematic areas in the current processes by establishing the performance characteristics of the current processes based on factors identified in the ECSA and Washington Accord accreditation requirements. In particular, the existing educational process needs to be scrutinized, and the performance gaps diagnosed.

Design "To Be": In order to design the "To Be," it is important to first of all identify the future objectives. For example, a detailed explanation of the requirements the education process wants to reach is essential. The phase also describes the different sub-objectives the process would achieve. The scope of this phase is to design and model all the courses that should be re-designed and also consider the relations between the different courses in a multi-disciplinary perspective.

Test and implementation of "To-Be" processes: The new process designed needs to be tested in order to verify the process logic, the usability, and the educational outcome that could be achieved. The test also includes an assessment of the resources allocation (students, academic staff, and facilities). The implementation consists of a road map for the new educational system implementation and roll-out. It contains descriptions of the implementation time frame, resources, new courses, training for the academic staff, and other related activities.

Continuous improvement: This phase consists of periodical evaluation of the performance of the educational processes. During this phase, it is possible to plan the time and the resources for the next re-engineering project.

This paper reports on the first 2 phases of the re-engineering procedure and the other phases will be reported after completion of the on-going exercise to develop quality and internationally recognised mechanical engineering program at FET.

4. Re-engineering the BEng (Mech) Program

The first two phases in the re-engineering process followed in the program review are described in this paper; i.e. 'Identify Processes' and 'Review, Update, Analyse "As Is"'.

4.1 Identify processes

In the identification process it has been recognized that there are a few relevant items which have to be aligned in order to satisfy ECSA requirements for accreditation. The following processes have been identified.

Curriculum structural requirements—ECSA has defined the structure of engineering curricula based on SAQA minimum credits by knowledge area.

Exit Level Outcomes—Considering the OBE approach required by the WA, the ECSA has identified ten exit level outcomes engineering students are to acquire during the educational process.

Resources—an institution that is to run an educational system which is capable to support the student in acquiring prescribed outcomes, has to provide different resources of good quality (academic staff and facilities—library, laboratories, computational space etc).

Student—it is important to analyze how the students are recruited, assessed and which kind of resources they need and really use. It is the only way to confirm that the Exit Level Outcomes are reached.

4.2 Review, update, analyse "as is"

A comparison between the BEng (Mech) program and ECSA accreditation requirements have been prepared and analyzed so as to identify the gaps in the former. Each gap is reported both quantitatively and qualitatively. Moreover, during the diagnosis some issues on how to re-design the program have been recognized. The review is performed on the four elements identified in the first step of the re-engineering process.

4.3 Curriculum structural requirements

The curriculum of the BEng (Mech) program has been assessed and analysed by identifying the courses which contribute to a particular element of interest. The contribution has been considered in '0–1' mode (i.e. 'yes' or 'no') and a course could contribute to more than one element. The assessment of a particular course's contribution to the graduate attributes, competency profile and exit level outcomes was based on the course descriptions. The comprehensive material submitted for actual accreditation by ECSA was used for an engineering program from South Africa. The detailed course (or module) description (or study guide) contains sufficient information on knowledge areas, exit level outcomes, competencies and capabilities achieved after successful completion of a course. In the case of BEng (Mechanical) program at UB the information from the course description (prepared in the same way as for South African program) was used. More information was also obtained from the program coordinator and through interviews with course lecturers.

The percentages used in Table 6 and Fig. 2 have been based on the ratio between the number of courses contributing to an element and the total number of courses. For example for ECSA Requirements and current B.Eng program, 10% and 8% of the courses contribute to Mathematical Sciences respectively (Table 6).

Two steps were taken in order to identify the gaps in the curriculum structure of the BEng (Mech) program at FET. At first, it was examined to ensure that the four discipline areas required for accreditation (i.e. Basic Science & Mathematics, Engineering, Applied Science and Complementary Studies) as prescribed by the Washington Accord are covered. Secondly, the B.Eng curriculum was analysed in terms of the ECSA curriculum structure using the percentage of credits required in each area (Table 6).

Although the WA does not prescribe any minimum percentage for each area, it is evident that the BEng. (Mech) curriculum is very strong in technical and theoretical areas and light in practical and professional skill competencies that can be promoted in design & synthesis and discretionary courses (Table 6).

The structure of the FET UB program seems to be well-aligned to ECSA requirements. There are however two discrepancies; the minor one in the Mathematical Sciences (the gap of 2%) and the major one in the Design and Synthesis area (3% difference). The development of skills in design and synthesis is essential to good engineering practice and technological innovation. Creativity skills are also normally introduced in that area. There is need to increase the elements of design and synthesis in the program. It can be either by introducing a separate course in that area or by increasing the design and

Table 6. Curricula program structure

Area	ECSA Requirements	BEng. (Mech) Program
Mathematical Sciences	10%	8%
Basic Sciences	10%	12%
Engineering Sciences	30%	34%
Design and Synthesis	12%	9%
Computing and IT	3%	5%
Complementary studies	10%	11%
Discretionary	25%	22%

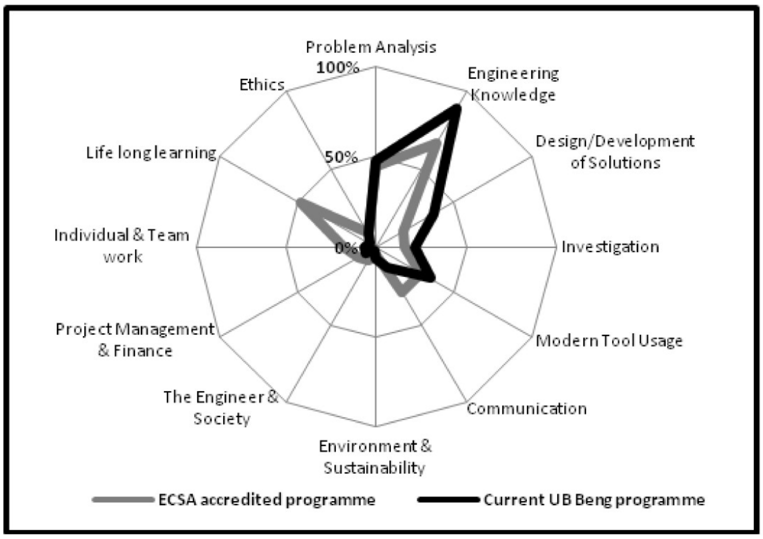

Fig. 2. Mapping Graduate attributes of BEng (Mech) and ECSA accredited programs.

synthesis content in the existing courses. As the existing courses cover all areas of mechanical engineering it is suggested to increase design and synthesis component in the existing courses. Beyond synthesis, creativity and design, engineering students must acquire skills in innovation and entrepreneurship. Innovation involves much more than mastering emerging science and technology. It involves how to take this knowledge to the next stage of providing service to society [34].

The curriculum of the BEng (Mech) program has also been mapped considering three elements; Graduate Attributes, Competency Profile and Exit Level Outcomes. Those elements are based on the OBE and the B.Eng (Mech) program has been compared with a similar but accredited program from one of the universities in South Africa (Figs. 2, 3 & 4). The data used in the following figures have been obtained by calculating the number of courses contributing to each element as a percentage of the total number of courses in the curriculum. The analysis was done by inspecting the course descriptions and interviewing lecturers in charge. Using the figures it is quite easy to identify deficiencies in the current program. It can be observed that unlike the ECSA accredited program, the BEng (Mech) FET UB is skewed towards the Knowledge area in Figs. 2–4.

Figures 2 and 3 indicate that the major emphasis of the program is to provide technical knowledge

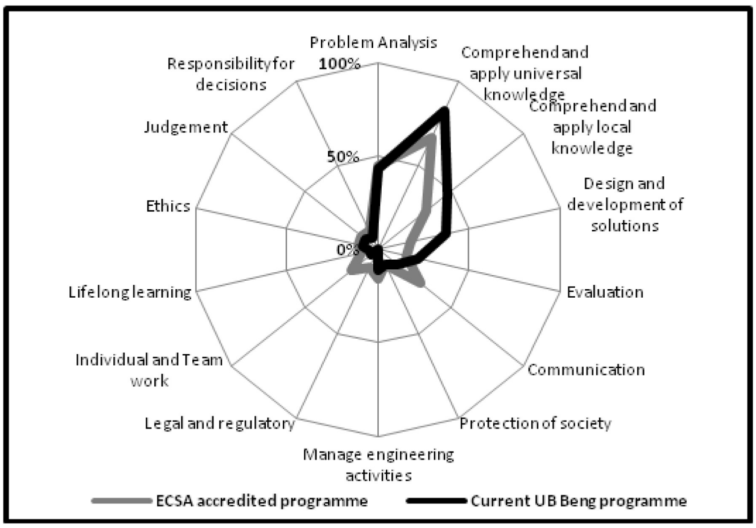

Fig. 3. Mapping Competency profiles of BEng (Mech) and ECSA accredited programs.

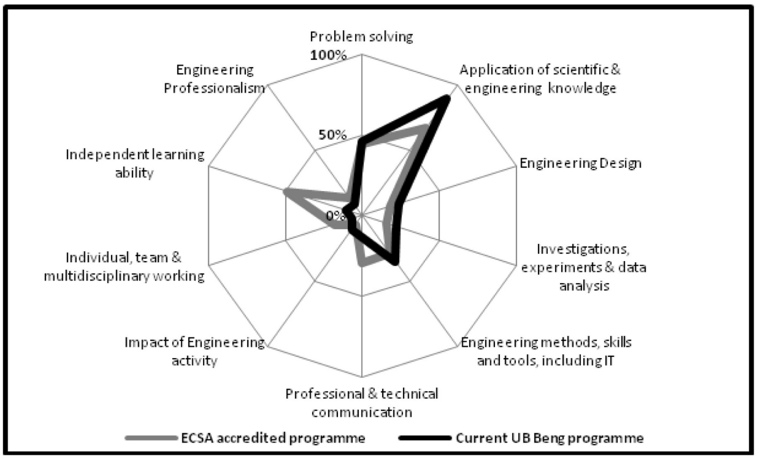

Fig. 4. Mapping Exit Level Outcomes of BEng (Mech) and ECSA accredited programs.

and basic engineering skills. There is not enough emphasis on professional engineering skills including communication, engineer orientation in the society, management and also on general skills like lifelong learning or team work.

In terms of Exit Level Outcomes (Fig. 4) there are visible gaps between the program and the ECSA requirements. It especially applies to independent learning abilities and communication. In comparison to a similar program in South Africa the competency profile of the graduate is lacking also in terms of communication, team work and legal and regulatory issues. In terms of graduate attributes the identified gaps are in life-long learning, team work and communication.

There is also some lack of legal and regulatory issues, project management and finance in the FET UB program. Courses in those areas are important in order to develop an educational process capable of "*producing*" globally relevant engineer. They must provide the student an understanding of the global economy, ability to comprehend and work within other cultures, work effectively in multinational teams, communicate across nations and peoples,(and, in particular in the developing countries) and understand the great challenges in the world. However, only few courses provide the student competencies on the impact of engineering activities on the society and knowledge about engineering professionalism. Also Figs. 2 and 3 shows that there is an insignificant level of ethics component in the curriculum either in the engineering or general education courses. Ethics should be introduced into the program as a separate course or incorporated in already existing courses. In general, the FET UB program should increase the professional global competencies which are the key characteristics of modern engineering graduates.

From the list of deficiencies it can be concluded that the major challenge in the program is not its content but its delivery. Most of the findings can be attributed to a traditional teaching style which is not based on what the student can learn but on what the lecturer can teach. For example, professional engineering skills (sometimes referred to as 'soft' skills) including communication, general skills like lifelong learning and team work, also engineer position in the society should be addressed by different teaching/learning approaches and not by introduction of new courses. Engineering curriculum is already so loaded that it may be difficult to introduce more general courses without compromising engineering hard skills.

The traditional approach adopted in the teaching activities is also confirmed by the fact that few courses adopt techniques to improve team and multidisciplinary working skills. Only two courses have a project based examination. Clearly, to fill this gap, the education style needs to shift increasingly away from the lecture-laboratory approach of the sciences to more active learning experiences that develop problem-solving skills, team building, creativity, design, and innovation. Engineering faculty must create discovery-oriented learning environments that capitalize on the full power of new communication, information, and visualization technologies.

4.4 Program resources

Student—The admission requirements for BEng (Mech) program at UB is the Botswana General Certificate of Education (BGCSE). All engineering students follow General Science program in Year 1 and in order to be registered for engineering programs (i.e. in Year 2) they need to achieve a minimum grade of Credit in mathematics and physics. This regulation is developed with the aim to have homogeneous knowledge classes and it is aligned with the ECSA requirements. However, it is still to be determined whether the level of knowledge of students admitted to engineering programs is similar to those of students in similar accredited programs.

Academic staff—There is no noticeable deficiency in the qualification and experience of staff teaching on the B.Eng (Mech) program i.e. the faculty have profiles comparable to those in similar institutions in the region and internationally. However involving the academic staff in the re-design of the curriculum can be a challenge. This may partly be because the time and effort committed to the accreditation process is not normally considered in distribution of other departmental activities e.g. by reduction of the teaching loads. Also, the fact that such efforts are not having enough recognition in assessment and promotions of faculty certainly creates an additional setback.

Facility Resources—The FET UB is a relatively new faculty and faces some problems in terms of laboratories, computing and support facilities. The difficulties are sometimes related to the power supply. Frequent black-outs create challenges in the management of the lectures and practical activities. In this sense, it is quite demanding to successfully plan access for the students to the laboratories or to adopt new IT tools for teaching. Another issue is related to computing facilities, in particular to the internet connection: Africa, in general, is currently the most under-served continent in terms of the information and communication technology [35]. Connectivity, capacity and content are the three basic conditions for the use of the Internet. At the FET UB, the internet connectivity is provided to all the academic staff and students; however it is often challenging to use it due to the slow speed of the connection. In this context, it is difficult to acquire and share knowledge, to collaborate with other institutions and share documents. Moreover, due to the slow speed of the connection it is difficult to adopt software which requires online server connection, employ e-learning facilities for interactive teaching and learning, streaming videos or live lectures.

The library facility is well-resourced as current and state of the art materials and publications are readily available. Subject librarians are also adequately qualified and trained.

Industry—Another problem often faced in developing countries is the lack of significant input from industry into the review of engineering programs. For example, it is typically difficult to find large engineering companies prepared to commit time and effort in order to influence local engineering education. Consequently, industry is largely represented in program review only by government departments and small businesses with limited experience and knowledge of re-designing engineering programs.

5. Redesign, implementation and continuous improvement phases: The OBE approach

The OBE approach can be used to transform the existing BEng (Mech) program and eliminate the deficiencies and gaps previously identified. The ultimate goal is the accreditation of the program by ECSA but the immediate goal is the improvement of the structure and delivery of the program.

The four principles of OBE shown in Table 7 guide the transformation of the program and taken together they strengthen the conditions for success for both learner and teacher [36]. The systematic approach [37] of the implementation of the OBE principles and some suggestions to enhance acceptability of the FET programs are presented in Table 7.

The expected changes in the BEng (Mech) program should be in terms of a strong curriculum re-engineering and the adoption of flexible delivery methods. Pedagogical techniques should be both innovative and diverse. Such techniques are both

Table 7. Outcomes Based Principles—explanation & application

OBE Principles	Redesign Issues	How to implement
Clarity of focus	Focus on what learners will be able to do successfully	Help learners develop competencies Enable predetermined significant outcomes Clarify short & long term learning intentions Focus assessments on significant outcomes
Design	Begin curriculum design with a clear definition of the significant learning that learners are to achieve by the end of their formal education	Develop systematic education curricula Trace back from desired end results Identify "learning building blocks" Link planning, teaching & assessment decisions to significant learner outcomes
High expectations	Establish high, challenging performance standards	Engage deeply with issues to facilitate learning Push beyond where learners would normally have gone
Expanded opportunities	Do not learn same thing in same way at the same time	Provide multiple learning opportunities matching learner's needs with teaching techniques

Table 8. *OBE* Assessment Tools

Direct Assessment	Indirect Assessment
Quizzes	Reports and minutes of meetings with Industrial Advisors
Tests	Reports and minutes of meetings with External Examiners
Final Examination	Alumni survey
Assignments	Employer survey
Projects	Parents survey
Final Year Project	Academic Staff Perception Survey
Lab Experiments	
PBL/ POPBL	

essential in order to comply with the OBE system and also to encourage and inspire students. Instructional methods to enhance delivery include active-learning techniques (i.e. hands-on activities and in-class demonstrations) to motivate students and give them a deeper conceptual understanding of the underlying principles. Other innovative techniques, such as problem-based learning, project-based learning, cooperative learning, experiential learning or peer-assisted learning can engage students fully and usually promote the possibility of covering different learning styles [22–24].

Moreover, as discussed in the OBE methodology and in the ECSA requirements, it is necessary to introduce a variety of assessment tools to analyse the Exit Level Outcomes reached by the students (Table 8). The results of the assessment and evaluation should be used in the Continuous Improvement phase in the re-engineering of the curriculum.

It is important to emphasize that the changes suggested in the delivery methods and assessment tools require commitment of staff members. However, such process demands encouragement and support from the management of the institution, for example, by providing financial and organizational backing.

Enhanced support system will easily facilitate introduction of new principles in learning/teaching approach.

6. Conclusions

The paper describes the process of re-engineering used for the transformation of the BEng (Mech) program in order to align it with the accreditation requirements. The study adopts a Business Re-engineering Process (BRP) in which engineering education is considered as a process. A modified McKinsey's re-engineering model was chosen as a tool to re-engineer the educational system. The model involves five broad phases, namely, process identification, review and analysis (diagnosis), redesign, test and implementation and monitoring and evaluation (continuous improvement).

The curriculum is mapped according to the graduate attributes, competency profiles and the ECSA Exit Level Outcomes. In terms of Exit Level Outcomes independent learning abilities and communication have been identified as clear gaps between the existing program and ECSA accreditation requirements. In terms of the competency profile communication, team work and legal and regulatory issues are the most apparent deficiencies. In terms of graduate attributes the identified gaps are in life-long learning, team work and communication.

From the identified deficiencies it can be concluded that the major shortcoming of the program is not necessarily its technical content but its mode of delivery. It is recommended that innovative flexible delivery methods should be used as teaching styles. The teaching and learning need to shift increasingly away from the lecture-laboratory approach to more active learning experiences that promote problem-solving skills, team building, creativity, design, innovation and life-long learning. The program must employ discovery-oriented learning environments that capitalize on the full power of modern communication schemes, information gathering, and visualization technologies.

The identified deficiencies could be eliminated through a paradigm shift and change of focus from teaching to learning. The actions required are both in the curriculum and also in pedagogic approach. As the shape of the curriculum seems satisfactory, it is the teaching styles which require some changes and special attention. It requires changes in the academic staff teaching approach and attitude. Challenges related to such a paradigm shift in teaching styles would be addressed in further studies.

As the re-engineering process is yet to be completed there is only anecdotal evidence that business procedure can be successfully used for engineering education process. However, apart from critical analysis of the existing program the process has offered many new experiences to all involved in the transformation. For some faculty, the exercise has triggered interest in engineering education as an important aspect of their academic duties and career.

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