Using outcomes-based education as a strategy for improving the academic achievement of senior engineering students

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Abstract: - The advent of outcomes based education (OBE) in South Africa during the 1990’s has resulted in a wealth of written material on the subject ranging from textbooks to accredited articles to conference papers. The purpose of this paper is not to provide an in-depth discussion on what and why of OBE, but to present how its underlying principles have been implemented into the practical assignments of a telecommunications module in an effort to improve academic achievement. This implementation is discussed from the point of pairing OBE with exit-level outcomes (ELO) specified by the Engineering Council of South Africa (ECSA) which must be achieved by engineering students in Higher Education.

Key-Words: - Outcomes based education; throughput rate; Radio Engineering 3; Exit-level outcomes

1 Introduction
“It’s one thing to open the doors of learning, quite another to change what’s behind them” [1]. These words well convey the enormous challenge faced by educational institutions in bringing about meaningful change to existing educational frameworks. Many academics feel that OBE has not proved to be a meaningful change, but has rather contributed to further concerns and struggles within the teaching and learning environment. This has largely been due to a lack of understanding of what was to be implemented as shown by a number of international studies from New Zealand [2] to the USA [3]. Studies from South Africa [4, 5] have also confirmed this fact.

These studies are further supplemented by an abundance of literature attempting to explain the philosophy and ingredients of OBE as well as its management, instructional and assessment strategies [6, 7]. The purpose of this paper is, however, to highlight how the principles of OBE have been implemented in an electrical engineering module, termed Radio Engineering 3, by initially pairing the seven critical cross-field outcomes (CCO) of OBE with the six ELO specified by ECSA. These ELO have been used to design ten different practical assignments which form 40% of the student’s final mark. Successfully completing these practical assignments often result in students passing this module, thereby achieving academic success. Assessment strategies used to determine academic success are presented along with results of student achievement for a five year period. It must be emphasized that OBE was never conceived as a single unitary model for guiding the process of curriculum change, but has rather been interpreted, developed and implemented in various ways [8].

2 Exit-level outcomes versus critical cross-field outcomes
ECSA [9] is responsible for accreditation of engineering programmes and ensuring quality education within the various fields of engineering. ECSA has specified six ELO, which need to be met by engineering students in the National Diploma programme, if they are to become qualified artisans and professional technicians and technologists within the industrial sector. These six ELO are very similar to the seven CCO underpinning OBE, which have been accepted by the South African Qualifications Authority (SAQA) [10], as illustrated in Table 1.

These six ELO are met by means of theoretical and practical instruction within an electrical engineering module, termed Radio Engineering 3. This module is designed to aid students to understand radio station broadcasts and reception principles with regard to frequency generation, modulation and transmission.

Radio Engineering 3 is offered over a period of 14 weeks and involves five theory sections and 10
practical assignments. The practical assignments (done in a laboratory) are designed to complement and reinforce the theory (offered in a classroom) [11]. Table 2 shows the 10 practical assignments which have been designed to meet specific ELO.

Table 1: Similarities between ELO and CCO

<table>
<thead>
<tr>
<th>Exit-level outcomes endorsed by ECSA</th>
<th>Critical cross-field outcomes accepted by SAQA for OBE</th>
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</thead>
<tbody>
<tr>
<td>1 – Problem solving <strong>Outcome:</strong> Apply engineering principles to systematically diagnose and solve well-defined engineering problems.</td>
<td>1 – Problem-solving skills Identify and solve problems and make decisions using critical and creative thinking</td>
</tr>
<tr>
<td>2 – Application of scientific and engineering knowledge <strong>Outcome:</strong> Demonstrate application of mathematical, science and engineering knowledge in an engineering environment.</td>
<td>4 – Research skills Collect, analyze, organize and critically evaluate information</td>
</tr>
<tr>
<td>3 – Engineering design <strong>Outcome:</strong> Perform procedural design of well-defined components, systems, works, products or processes to meet desired needs within applicable standards, codes of practice and legislation.</td>
<td>6 – Technological skills Use science and technology effectively and critically, showing responsibility towards the environment and health of others</td>
</tr>
<tr>
<td>4 – Communication <strong>Outcome:</strong> Communicate technical, supervisory and general management information effectively, both orally and in writing, using appropriate language and terminology, structure, style and graphical support.</td>
<td>5 – Communication skills Communicate effectively using visual, symbolic and/or language skills in the various modes</td>
</tr>
<tr>
<td>5 – Engineering management <strong>Outcome:</strong> Apply self-management principles and concepts relating to the development of projects and/or operations within an engineering environment.</td>
<td>3 – Management skills Organize and manage themselves and their activities responsibly and effectively 2 – Collaborative skills Work effectively with others as members of a team, group, organization and community.</td>
</tr>
<tr>
<td>6 – Application of complementary knowledge <strong>Outcome:</strong> Demonstrate a critical awareness of the impact of engineering activity on the social, industrial and physical environment, and of the need to act professionally within own limits of competence.</td>
<td>7 – Holistic skills Demonstrate an understanding of the world as a set of related systems by recognizing that problem-solving contexts do not exist in isolation</td>
</tr>
</tbody>
</table>

Table 2: The 10 practical assignments designed to meet specific ELO

<table>
<thead>
<tr>
<th>Laboratory assignment</th>
<th>Desired outcomes</th>
<th>ELO</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 – The FM signal</td>
<td>Calculate modulation index, deviation, modulating frequency and total output power using a computer-based spectrum analyzer</td>
<td>2 4 5</td>
</tr>
<tr>
<td>2 – The AM signal</td>
<td>Calculate modulation depth using the trapezoidal pattern and evaluate total output power fluctuations using a spectrum analyzer</td>
<td>2 4 5 6</td>
</tr>
<tr>
<td>3 – The SSB signal</td>
<td>Evaluate carrier and sideband suppression in terms of international standards and grasp RF power meter operation</td>
<td>2 4 5</td>
</tr>
<tr>
<td>4 – The FM stereo transmitter</td>
<td>Grasp stereo multiplexing and the purpose of pilot frequencies and calculate phase differences for a PLL based FM modulator</td>
<td>2 4 5</td>
</tr>
<tr>
<td>5 – The phase-lock loop</td>
<td>Calculate a free-running frequency along with capture and lock ranges and grasp frequency dividers which are used in synthesizer circuits</td>
<td>2 4 5</td>
</tr>
<tr>
<td>6 – Transmission lines</td>
<td>Evaluate balanced transmission lines for open, short and matched circuit conditions, using time domain reflectometry</td>
<td>1 2 4 5</td>
</tr>
<tr>
<td>7 – Radio receivers</td>
<td>Calculate the input frequency range, frequency rejection and selectivity of tuned circuits using time domain analysis</td>
<td>2 4 5</td>
</tr>
<tr>
<td>8 – The AM transmitter</td>
<td>Calculate harmonic multiplication values and grasp the relationship between modulation depth and total output power using the envelope</td>
<td>2 4 5</td>
</tr>
<tr>
<td>9 – Antenna design</td>
<td>Design and construct a Yagi-Uda antenna along with a balun</td>
<td>1 - 6</td>
</tr>
<tr>
<td>10 – Frequency synthesizer design</td>
<td>Design and construct a frequency synthesizer using a phase-lock loop</td>
<td>1 - 6</td>
</tr>
</tbody>
</table>

ELO 2 occurs in all ten practical assignments as mathematical techniques are often a major component of many engineering courses [12].

These 10 practical assignments further involve group work or cooperative learning where two students are required to work together through the semester. ELO 4 is therefore also present in all the practical assignments, as students have to communicate effectively within their group. They also need to communicate effectively with the
A lecturer who orally evaluates a number of the assignments (4-7) in the laboratory.

Detailed step-by-step guides are used by the engineering students to successfully complete the assignments in the laboratory. Students therefore need to manage their progress in the laboratory in order to complete the assignment within the allotted time. They also need to complete detailed written reports of four specific practical assignments, which need to be submitted the following week. This report must be compiled according to a fixed structure which again requires self-management principles (ELO 5).

The other ELO (1, 3 and 6) occur in a number of other practical assignments depending on its intended purpose or desired outcomes.

### 3 Assessment strategies

The assessment of student learning in the Radio Engineering 3 laboratory is measured through exercises, peer-evaluations, practical assignments and projects. All these assessment strategies form part of the continuous assessment required by OBE [6, 13].

Exercises are used to determine what prior knowledge students possess at the beginning of the course. This helps the lecturer to determine which aspects of the laboratory assignments require more clarification and time.

Peer-evaluations are used with practical assignment 9 and 10 (which is also project work), where students are asked to judge the performance and quality of the completed projects (being an antenna and frequency generator).

Practical assignments 1 – 8 are assessed with predefined rubrics which results in criterion referenced grading. Criterion-referenced measurement compares student achievement to a lecturer standard instead of to the achievement of other students [14].

### 4 Results

The target population was restricted to students registered for the module Radio Engineering 3 for the time period of 2005 – 2009. All enrolled students were included in the research which gives rise to a probability sample (an average of 23 students per semester over a 10 semester period results in n=233).

Fig. 1 illustrates the semester throughput rates for the past five years in which the principles of OBE were applied. Throughput rate is defined as the number of students in Higher Education who successfully complete a module compared to the number who originally enrolled for that same module, and is expressed as a percentage [15]. A very noticeable aspect of this descriptive statistic is that the throughput rate never fell below 85 % for the time period of interest.

Fig. 2 shows the average mark of the five theoretical tests (written tests based on the classroom instruction) and the average mark of the ten practical assignments (completed in the laboratory). The student’s final mark is a combination of 60% of the theoretical mark and 40% of the practical mark. A noteworthy aspect is that the practical averages always outweigh the theory averages which suggest that senior engineering students are more adept at acquiring skills (practical work) than knowledge (theory work). This bodes well for the South African industry which is currently experiencing a skills shortage across all disciplines. This also satisfies ECSA who are primarily interested in what a person can do, rather than in what a person knows.
enjoyed the practical assignments and felt that they were very relevant to the theory work covered in the classroom.

![Bar chart](image)

Fig. 3. Student feedback regarding satisfaction, relevance and intricacy of the practical assignments

5 Conclusion

The seven CCO (OBE principles) were correlated to the six ELO specified by ECSA, and then adapted and implemented to the practical assignments within the module Radio Engineering 3. These outcomes are specifically applied to encourage students to apply scientific and engineering knowledge in an attempt to solve real world engineering problems. Engineering design (construction), communication (assessment) and management (time) are also advanced within the laboratory.

Feedback from students has also been positive as they enjoyed the practical assignments scheduled in the laboratory, feeling that they were very relevant to the theory presented in the classroom.

A significant fact of this study is that OBE can be successfully implemented in engineering modules to improve student achievement. This was verified by how OBE positively influenced the academic success of Radio Engineering 3 students, as the throughput rate remained high over the five year period of study. “Yes, open a door of learning, and see if you can change what’s behind it to the benefit of all involved!”

References:


