Development of technical skills in Electrical Power Engineering students: A case study of Power Electronics as a Key Course

I S Hussain\textsuperscript{1} and Fazrena Azlee Hamid\textsuperscript{2}

\textsuperscript{1}Department of Electrical Power Engineering, College of Engineering, Universiti Tenaga Nasional, Selangor, Malaysia
\textsuperscript{2}Department of Electronics & Communication Engineering, College of Engineering, Universiti Tenaga Nasional, Selangor, Malaysia

Corresponding author: idasuzana@uniten.edu.my, fazrena@uniten.edu.my

Abstract. Technical skills are one of the attributes, an engineering student must attain by the time of graduation, as per recommended by Engineering Accreditation Council (EAC). This paper describes the development of technical skills, Programme Outcome (PO) number 5, in students taking the Bachelor of Electrical Power Engineering (BEPE) programme in Universiti Tenaga Nasional (UNITEN). Seven courses are identified to address the technical skills development. The course outcomes (CO) of the courses are designed to instill the relevant technical skills with suitable laboratory activities. Formative and summative assessments are carried out to gauge students’ acquisition of the skills. Finally, to measure the attainment of the technical skills, key course concept is used. The concept has been implemented since 2013, focusing on improvement of the programme instead of the cohort. From the PO attainment analysis method, three different levels of PO attainment can be calculated: from the programme level, down to the course and student levels. In this paper, the attainment of the courses mapped to PO5 is measured. It is shown that Power Electronics course, which is the key course for PO5, has a strong attainment at above 90%. PO5 of other six courses are also achieved. As a conclusion, by embracing outcome-based education (OBE), the BEPE programme has a sound method to develop technical psychomotor skills in the degree students.

1. Introduction
Employers in the industries have high expectations on engineering graduates once they started to work. To ensure a smooth entry into the industries, engineering graduates are expected to possess employability skills needed by the employers. In Malaysian Engineering Employability Skills framework [1], the employability skills are divided into three components; personal attributes, personal skills, and knowledge. The three components listed are comparatively similar to affective, psychomotor and cognitive domains as suggested in [2].

Psychomotor skills are one of the important outcomes for the engineering graduates to acquire [1], [3], [4]. The psychomotor has psycho (or knowledge) element and motor element. In UNITEN, from the 12 POs statements, there are two POs dedicated to the psychomotor domain; PO5 which assess the technical skills and PO9 which assess the students’ communication skills [5] which are as per
requirement in EAC [6]. Competency to use modern engineering tools and software are imperative in the working environment to guarantee quality standards and to meet engineering specifications. Furthermore, soft-skills which includes communication, teamwork and leadership abilities are important factors to be successful in the workplace. Therefore, curriculum development of these attributes and skills need to be planned wisely.

Technical skills are attainable in laboratory experiments which are integrated into the engineering curriculum [2]. In order to assess the technical skills attainment, a comprehensive analysis of all related courses addressing technical skills should be done. This means that a review of engineering laboratory courses will provide insight on how technical skills are developed in an engineering degree curriculum. From literature survey, a full review of lab courses for an Electrical Engineering programme is available in [7]–[9]. Whereas, papers [4], [10], [11], focuses on a specific lab course only. A proper methodology to ensure the achievement of technical skills from laboratory courses or laboratory curriculum does not exist.

Therefore, this paper aims to fulfill two objectives in order to confirm that BEPE students in UNITEN have strong technical skills. The first objective is to report UNITEN’s BEPE laboratory curriculum in particular the technical aspect of the psychomotor skills (PO5). The technical skills development will be described starting with designing of COs for the courses, a listing of equipment and software used and assessments conducted. The second objective is to describe the direct measurement method used, a key course concept, to gauge the achievement of the technical skills as described in [5], [12]. The key course concept has been implemented in all engineering programmes in UNITEN throughout the 4-year degree programme since 2013 [5].

The paper is presented as follows: In Section 2, the development of technical skills in students as part of the OBE process is described. The validation of the development process, corroborated by PO attainment results (at student, course and programme level), are presented in Section 3.

2. Methodology to develop technical skills (PO5)
The technical skills development process of BEPE’s PO5 is part of the OBE process in UNITEN. It is generic and can be applied to any PO. There are three steps in the development process,

i) Mapping of the courses to the PO
ii) Determine delivery and assessment methods for each PO
iii) Determine the performance criteria and grading levels

2.1. Mapping of the courses to the PO
The development process starts with mapping of all the courses that that would contribute significantly to the PO5. The courses can be classified into two categories [12], supporting courses and a key course.

- Supporting courses: In these courses, the students are expected to learn and accumulate their knowledge/ability with respect to the PO prior to the key course.
- Key course: The course is a third or final year course. The PO attainment of the key course is used to indicate the overall PO attainment for the programme.

The supporting courses for PO5 consist of five lab courses and Digital Signal Processing (DSP) course that also has a lab component. Whereas Power Electronics is the key course for PO5, it is a core subject taken by BEPE students in the 3rd Year, which is the 6th semester of their studies [12].

Once the key and supporting courses have been identified, the CO, as well as teaching and learning activities at the course level, are developed. Table 1 lists COs which are mapped to PO5 for the seven courses. The depth and breadth of the technical skills covered by each course are indicated by the COs descriptions as well as the list of components, equipment, and software used. The final year is not included in table 1 since it is devoted to elective courses.
2.2. Determine delivery and assessment methods related to the PO

It is important to identify a suitable delivery method to impart transferable skills to the students. The psychomotor domain has psycho (or knowledge element) and motor elements. The psycho element (understanding and reasoning skills) are assessed in the lab reports where the students clarify, illustrate and document ideas. The assessment for the motor element is done by evaluating the students’ ability to perform the experiments and the simulations. The delivery and assessments vary according to courses and can be classified into (i) controlled laboratory experiments (laboratory work, practical test), (ii) experimental investigations, and (iii) projects (problem-based or project-based learning (PBL)).

Table 2 describes lab activities and assessments for the seven courses mapped to PO5. The lab activities form part of the assessments of the CO listed in table 1. All the seven courses have a hands-on lab. Four courses assessed group problem-based learning or project-based learning. Each lab activities contribute to the final grade marks as shown in figure 1.

Referring to figure 1, Electrical Machines Lab has the highest total PO5 assessments at 60%. This lab course is highly related to the core of the BEPE programme. Power Electronics has 30% of its assessments contributing to PO5. The least PO5 assessment is DSP course at 7.5%. This is acceptable as BEPE students only need an exposure to the DSP course.

2.3. Determine the performance criteria and grading levels

A standard assessment rubric is designed, based on [2], [3], to assist the instructors in assessing students’ performances fairly and consistently. The performance criteria enabled the explicit CO and the PO attainments to be measured [14].

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Table 1. Courses mapped to technical skills development (PO5).

| Course code & Course name | Course Outcomes mapped to PO5 | Components, equipment, software used |
|---------------------------|-------------------------------|--------------------------------------|
| 1st Sem. EEEB111 Electrical/ Electronic Measurement Lab | demonstrate measurement of resistance, DC voltage, node voltage, current | DC power supply, function generator, digital multimeter, analog meter, oscilloscope, resistors, capacitors, inductors |
| | construct 1st & 2nd order circuit, op. amplifier circuits | |
| | simulate the circuits using modern tools | |
| 2nd Sem. EEEB161 Digital Logic Design Lab | construct digital circuits | TTL 74 series basic logic gates, digital logic experimenter kit, Quartus II and ModelSim-Altera |
| | simulate digital circuit designs using modern tools | |
| 3rd Sem. EEEB141 Electronics Design Lab | assemble basic electronics prototypes | Power supplies, diodes, BJTs, MOSFETs, analog & digital meters, oscilloscope, LTSPICE |
| 5th Sem. EEEB281 Electrical Machines Lab | construct wiring connections for experiments | DC & AC machines, analog & digital meters, oscilloscope, AC & DC supplies |
| 6th Sem. EECB351 Communication System Lab | investigate the generation and reception of AM & FM | EMONA board, oscilloscope |
| | investigate the generation and reception of digital modulation | |
| 6th Sem. EEEB363 Digital Signal Processing | simulate the DSP concepts using MATLAB and Real-Time laboratory implementation on DSP board | DSP Starter Kit (TMS320C6713), MATLAB & Code Composer Studio (CCS) |
| 6th Sem. EEEB393 Power Electronics | construct various types of converters | Power supplies, function generator, digital & analog meter, oscilloscope, resistors, capacitors, inductors, diode, IGBT, thyristor, DC motor, MATLAB |
| | simulate the designed system using modern tools | |
For Power Electronics course, the performance criteria to assess the technical skills are defined as follows,

i) Selection of tools/resources: The students know the types of equipment and connectors required to set up the experiment from the list of equipment given.

ii) Familiarity with tools: The students are capable to make connections based on the diagram given and set the controller and analog meter settings with minimal assistance.

iii) Operation of tools: The students are capable to conduct the experiments to obtain the measurements and waveform plots according to the instruction given in the lab manual.

iv) Integration of tools: The students are capable to reconstruct the connections made to measure and display signals which are not shown in the lab manual.

3. Attainment of the technical skills (PO5)

Descriptions on how a PO attainment is measured and evaluated directly is described in the EAC Self-Assessment Report [12] and reported in [5]. The attainment is computed by using Outcome Based Education online system (OBEos), a program developed by the university to evaluate the attainment of COs and POs at the end of each semester. The system also helps in monitoring and standardizing the Continual Quality Improvement (CQI) process. Based on a set performance criteria target, the CO and the related PO attainment addressed by the course can be determined. Table 3 shows how PO5 attainment is measured at student, course and programme levels. CQI process done at each level are also briefly described.
Table 3. Measurement of PO attainment at student, course and program levels.

| Target | Reporting method | CQI process |
|--------|------------------|-------------|
| Student level | Students obtained mark $\geq$ 40% of the PO | Semester Programme Outcome Score (SPOS) Report as shown in figure 2 | From the SPOS report, the student is aware of his/her PO attainment for further improvement |
| Course level | $\geq70\%$ of the students taking the course attained the PO | End-of-Semester Course Assessment Report (eSCAR) | From the eSCAR generated by the OBEos, instructors of a course can plan for future improvising actions [12] |
| Program level | $\geq70\%$ of the students taking the key course attained the PO | Programme Assessment Report and Planning (PARAP) | If the PO target of the key course is not attained, the supporting courses mapped to the PO are also reviewed |

Figure 2. A sample of SPOS report of a student; EX=excellent (80-100%), GD=good (60-79%), SF=satisfactory (40-59%) and PR=poor (<40).

Figure 3. PO attainment results for PO5 courses for Sem. 1 and Sem. 2 15/16

Figure 3 shows the PO attainment results for the courses mapped to PO5 in Semesters 1 and 2, 2015/2016. All the supporting courses achieved at least 70% and above, which means that PO5 was attained in both semesters. The PO attainment results for Power Electronics, in Semesters 1 and 2 2015/2016 were 97.1% and 97.3%, respectively.

4. Conclusions

This paper has presented the method to develop psychomotor skills related to the hands-on engineering aspect of the BEPE programme in UNITEN. This method is based upon incorporating related POs into courses from Semester 1, until the final semester of the studies. The POs attainments are measured each semester, and using the key course concept, the programme level attainment of the PO can be monitored.
The results of PO5 attainment, in the 2015/2016 academic year, for courses mapped to PO5 are presented and discussed. The results of PO attainment for the key course of PO5, Power Electronics is more than 90%. All supporting courses also have PO5 being achieved. This indicates that PO5 is attained at both BEPE programme level and course level. Based on these results, any further improvements to the BEPE programme related to psychomotor skills can be done since the contributing content and assessments related to the PO can be tracked.

It can be concluded that the methodology to develop technical skills in BEPE students in UNITEN is well-established, and the performance can be tracked from an individual student level, up to courses and programme level. With this, it is anticipated that the graduates will be highly competent and are able to contribute in technical tasks as required by the employers once they are employed.

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