Assessment and Evaluation for Programme Learning Outcomes in Faculty of Mechanical and Manufacturing Engineering, Universiti Tun Hussein Onn Malaysia

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Abstract. Universiti Tun Hussein Onn Malaysia (UTHM) is the 15th of the 20 public universities established in Malaysia. UTHM consists of eight faculties. One of them is the Faculty of Mechanical and Manufacturing Engineering (FKMP). The programme offered – Bachelor of Mechanical Engineering with Honours (BDD), undergoes continuous auditing and accreditation by the Engineering Accreditation Council (EAC). To fulfill the requirement for accreditation, EAC requires the faculty to assess and evaluate the programme learning outcomes’ (PLOs) attainment of the graduates, such that all graduates are targeted to achieve the performance indicator (PI) upon graduation. This paper discusses the methods developed by the FKMP for PLOs’ measurement and evaluation. Two approaches are utilized in this regards, (i) the direct assessment based on students’ performance in courses, and (ii) the indirect assessment based the industrial and graduates’ perception. The PLOs’ attainment for graduates of cohort 2010-2012 are analysed in this study. Consolidation data shows that the PI for majority of the PLOs are achieved, indicating that the programme offered complies with the standard expected by different stakeholders.

1. Introduction

All engineering programmes in Malaysia are monitored closely by the Engineering Accreditation Council (EAC) through auditing and accreditation practices such that their qualities are ensured. Each engineering program is expected to fulfill the eight components of the accreditation requirements, in which the Programme Learning Outcomes (PLOs) are one of the elements being assessed by the EAC. PLOs are statements that describe what students are expected to know and be able to perform or attain by the time of graduation, that are linked to the domain of knowledge (cognitive), skill (psychomotor) and soft skill (affective) [1]. The programme of Bachelor of Mechanical Engineering with Honours (BDD) offered by the Faculty of Mechanical and Manufacturing Engineering (FKMP), Universiti Tun Hussein Onn Malaysia (UTHM) has 13 PLOs, which are established according to the Engineering Programme Accreditation Manual 2012 and the Ministry of Higher Education requirements. Table 1 summarises the PLOs of the BDD programme.


Table 1: The 13 PLOs of the BDD Programme offered by FKMP, UTHM

| PLO | Attribute                      | Domain  | Description                                                                                                                                 |
|-----|--------------------------------|---------|-------------------------------------------------------------------------------------------------------------------------------------------|
| 1   | Engineering Knowledge          | Cognitive | Apply knowledge of mathematics, science, engineering fundamentals and an engineering specialisation to the solution of complex engineering problems. |
| 2   | Modern Tool Usage              | Psychomotor | Create, select and apply appropriate techniques, resources, and modern engineering and IT tools, including prediction and modelling, to complex engineering activities, with an understating of the limitation. |
| 3   | Communication                  | Psychomotor | Communicate effectively on complex engineering activities with the engineering community and with society at large, such as being able to comprehend and write effective reports and design documentation, make effective presentations, and give and receive clear instructions. |
| 4   | Investigation                  | Cognitive | Conduct investigation into complex problems using research based knowledge and research methods including design of experiments, analysis and interpretation of data, and synthesis of information to provide valid conclusion. |
| 5   | Individual & Teamwork          | Affective | Function effectively as an individual, and as a number or leader in diverse teams and in multi-disciplinary setting.                           |
| 6   | Lifelong Learning              | Affective | Recognise the need for, and have preparation and ability to engage in independent and life-long learning in the broadest context of technological change. |
| 7   | Entrepreneurship               | Affective | Recognise the importance of entrepreneurship in mechanical engineering and its’ related discipline.                                        |
| 8   | Ethics                         | Affective | Apply ethical principles and commit to professional ethics and responsibilities and norms of engineering practice.                          |
| 9   | Project Management & Finance   | Affective | Demonstrate knowledge and understanding of engineering and management principles and apply these to one's own work, as a member and leader in a team, to management projects and in multidisciplinary environments. |
| 10  | Design/ Development of Solution | Cognitive | Design solution for complex engineering problems and design systems, components or processes that meet specified need with appropriate consideration for public health and safety, cultural, societal, and environmental considerations. |
| 11  | Problem Analysis               | Cognitive | Identify, formulate, research literature and analyse complex engineering problems reaching substantiated conclusions using first principles of mathematics, natural sciences and engineering sciences. |
| 12  | Environmental and Sustainability | Affective | Understand the impact of professional engineering solutions in societal and environmental contexts and demonstrate knowledge of and need for sustainable development. |
| 13  | The Engineer & Society         | Affective | Apply reasoning informed by contextual knowledge to assess society, health, safety, legal and cultural issues and the consequent, responsibilities relevant to professional engineering practice. |
Different methods, exemplary, formative and summative assessments, questionnaires, and interviews, can be used to assess the PLOs’ achievement. These methods, in general, can be classified into two categories: direct and indirect approaches [2]. The direct assessment approach systematically evaluate the students’ performance in the form of tests, final examinations, assignments, quizzes, projects and laboratory works, based on the established rubric. The indirect assessment approach, on the other hand, assesses the stakeholders’ perception in terms of students’ abilities to attain the PLOs. The consolidation of both direct and indirect assessment is useful to determine the quality of the programme and to provide analysis for continual quality improvement in the programme.

The PLOs are related to the course learning outcomes (CLOs). CLOs are statements that describe what students are expected to know and be able to perform or attain by the time of completing the courses, that are linked to the domain of knowledge (cognitive), skill (psychomotor) and soft skill (affective). Each course has its own course learning outcomes (CLOs), and has various delivery and assessment methods. Each CLO of the particular course is mapped to the particular PLO. Through the CLO-PLO mapping, the contributions of the CLOs towards the achievement of the PLOs can be evaluated. Figure 1 gives the CLO-PLO mapping of BDA24202 Computer Programming. There are 3 CLOs in this course, in which the CLO1, CLO2 and CLO3 are mapped to PLO1 Engineering Knowledge, PLO2 Modern Tool Usage and PLO6 Lifelong Learning, respectively. The performance indicator (PI) of each CLO is set as 100% students get 40% marks and above. In order to ensure that the CLOs are attained in the end results, the course lecturer develops the learning and teaching plans, selects the delivery and assessment method, and designs the assessment questions with proper rubric at the beginning of each semester. For instance, the lab sheets are used to assess whether the students are able to develop the program using C language (CLO2), which is related to the PLO2 Modern Tool Usage. Upon completing the course, the attainment of each CLO is measured and its contribution towards the particular PLO is analysed, which will be discussed further in the following sections.

Figure 1: CLO-PLO mapping of BDA24202 Computer Programming

2. Methods Used to Assess the Attainment of Programme Learning Outcomes
There are two methods of assessing the PLOs, namely (i) indirect assessment and (ii) direct assessment. The tools used in these assessments are summarised as in Table 2.

2.1. Indirect Assessment Approach
The PLOs attainment is assessed continuously by the FKMP through indirect assessment. The types of indirect evaluations and their mechanisms are explained as follows:
Table 2: Summary of Different Types of Assessments

| Types of Assessment | Platform | Method/Tools | Output |
|---------------------|----------|--------------|--------|
| Indirect            |          |              |        |
|                     | Industrial Advisory Committee (IAC) | Annual Meeting | Reports |
|                     | Adjunct Professor | Annual Meeting | Reports |
|                     | External Examiner | Annual Meeting | Reports |
|                     | Exit Survey | Survey | Reports |
|                     | Industrial Training Survey | Survey | Reports |
| Direct              |          |              |        |
|                     | Summative Evaluation of Students | CEPAT | Students’ achievement |
|                     | Formative Evaluation of Students | CEPAT / SAS / OBESYS | |

(i) Industry Survey
The industry survey is a tool to identify the needs and gaps of skill in industry based on the employer’s perception in terms of students’ abilities to attain the PLOs. The industry survey was conducted yearly during the Semester 3 of the third year academic session. The respondents are the employers of whom the FKMP students are undergoing the industrial training, including the managers, senior engineers and practicing engineers. The KPI set was 80% scored in both good and excellent index for each PLOs, as detailed out in the questionnaire.

(ii) Exit Survey
The Exit Survey refers to an indirect measurement method of students’ self-evaluation or individual perception for the assessment of qualities as prescribed in PLOs, which was conducted upon graduation. The graduates were required to assess themselves based on the questions as detailed out in the questionnaire. The KPI set was 80% scored in both good and excellent index for each PLO, as detailed out in the questionnaire.

(iii) Assessment by External Examiners/Adjunct Professor/Visiting Professors/Industrial Advisory Community (IAC)
The review from the External Examiners, Adjunct Professor, Visiting Professors and IAC regarding the appropriateness of the Faculty PLOs are taken during periodic review through various meetings.

2.2. Direct Assessment Approach
PLOs in FKMP were analysed by using online and offline systems. The established of management system (online and offline) used are divided into three systems as stated below:

(i) Offline system - Course Evaluation and Performance Analysis Tool (CEPAT)
(ii) Online system - Students Assessment System (SAS)
(iii) Online System – Outcome Based Education System (OBESys) evaluation

The CEPAT assessment template, which is an offline excel-based programming developed by the Faculty member, is capable in analysing the relations of the assessments for each courses to the CLOs and further to PLOs. The SAS and OBESys are online database system developed by the University (Information Technology Centre), which offer similar function with CEPAT with extra features. The different functions and features of the systems are as summarised in Table 3.
Table 3: Summary of Functions and Features of Different Systems of Assessments

| System | Basic Function (Marks compilation) | Features |
|--------|-----------------------------------|----------|
| 1. CEPAT | Continuous assessment | • Offline System  
• Analysis of CLO achievement  
• Mapping of CLO achievement to PLOs  
• Analysis of CLO and PLO KPI achievement |
|        | Final examination                  |          |
| 2. SAS  | Continuous assessment             | • Online System linked to TCIS  
• Systemised compilation of courses CQI |
|        | Final examination                  |          |
| 3. OBEsys |                              | • Online system linked to TCIS  
• Analysis of PLO achievement |

CEPAT and SAS were used to store continuous assessment and final examination marks of all students by the respective lecturer. CEPAT is managed by the Faculty’s OBE Committee meanwhile SAS is managed by the University. SAS is linked to the Total Campus Integrated System (TCIS). TCIS is an online system which integrates necessary information of personal, teaching and learning activities of each individual staff, regardless of academic or supporting staffs. The OBEsys system is managed by the Faculty’s OBE committee and is developed by the Information Technology Centre of UTHM. This system is capable to manage and measure the individual PLOs assessment.

The CEPAT is the main document used by the FKMP to measure the PLOs attainment. At the beginning of the semester, the course coordinators were given the authority to set up the mark weightage for each CLO towards the particular PLO marks. The mapping between the CLOs and PLOs were fixed by the faculty [3], but the mark weightage for each CLO can be varied in every semester, depending on the learning and teaching plan. The course coordinator will set up the weightage in TCIS and CEPAT, and the respective lecturers can fill up the marks in SAS and CEPAT afterwards. Figure 2 shows an example of the weightage distribution for each CLO to the PLO for BDA24202 Computer Programming in CEPAT.

![Figure 2: An example of weightage distribution of CLOs to PLOs in CEPAT BDA24202](image-url)
Figure 3: An example of attainment of each PLO in CEPAT BDA24202

Table 4: Cumulative PLO Attainments for Cohort 2010

| No. | Code    | Course                                | PLO 1 | PLO 2 | PLO 3 | PLO 4 | PLO 5 | PLO 6 | PLO 7 | PLO 8 | PLO 9 | PLO 10 | PLO 11 | PLO 12 | PLO 13 |
|-----|---------|---------------------------------------|-------|-------|-------|-------|-------|-------|-------|-------|-------|--------|--------|--------|--------|
| 1   | BDA 10102 | Engineering Drawing                   | 80%   | 80%   | 100%  |       |       |       |       |       |       |        |        |        |        |
| 2   | BDA 10203 | Statics                               | 88%   | 99%   | 99%   | 99%   | 99%   |       |       |       |       |        |        |        |        |
| 3   | BDA 10302 | Material Science                      | 92%   | 99%   | 99%   |       |       |       |       |       |       |        |        |        |        |
| 4   | BDA 10402 | Solid Mechanics I                     | 78%   | 100%  | 100%  |       |       |       |       |       |       |        |        |        |        |
| 5   | BDA 10502 | Fluid Mechanics                       | 78%   | 100%  | 99%   | 99%   |       |       |       |       |       |        |        |        |        |
| 6   | BDA 10602 | Creativity & Innovation               | 99%   | 99%   | 100%  | 100%  |       |       |       |       |       |        |        |        |        |
| 7   | BDA 10701 | Engineering Laboratory I              | 99%   | 99%   | 100%  |       |       |       |       |       |       |        |        |        |        |
| 8   | BDA 10801 | Mechanical Engineering Practice I     | 100%  |       |       |       |       |       |       |       |       |        |        |        |        |
| 9   | BDA 10901 | Mechanical Engineering Practice II    | 99%   | 99%   | 100%  | 100%  | 100%  | 100%  | 100%  |       |       |        |        |        |        |
| 10  | BDA 11051 | Dynamics                              | 99%   | 99%   | 100%  | 100%  |       |       |       |       |       |        |        |        |        |
| 11  | BDA 11101 | Thermodynamics I                      | 99%   | 99%   | 100%  |       |       |       |       |       |       |        |        |        |        |
| 12  | BDA 20101 | Mechanics of Machine                  | 99%   | 99%   | 100%  |       |       |       |       |       |       |        |        |        |        |
| 13  | BDA 20201 | Engineering Materials Selection       | 99%   | 99%   | 100%  |       |       |       |       |       |       |        |        |        |        |
| 14  | BDA 20301 | Computer Aided Design                 | 100%  | 99%   | 100%  |       |       |       |       |       |       |        |        |        |        |
| 15  | BDA 20401 | Engineering Laboratory II             | 99%   | 99%   | 99%   | 100%  |       |       |       |       |       |        |        |        |        |
| 16  | BDA 20501 | Engineering Laboratory III            | 99%   | 99%   | 99%   | 100%  |       |       |       |       |       |        |        |        |        |
| 17  | BDA 20601 | Engineering Laboratory IV             | 99%   | 99%   | 99%   | 100%  |       |       |       |       |       |        |        |        |        |
| 18  | BDA 28001 | Mechanical Engineering Practice IV    | 96%   | 100%  |       |       |       |       |       |       |       |        |        |        |        |
| 19  | BDA 28101 | Mechanical Engineering Practice V     | 97%   | 99%   | 100%  |       |       |       |       |       |       |        |        |        |        |
| 20  | BDA 30101 | Solid Mechanics II                    | 93%   | 99%   | 100%  |       |       |       |       |       |       |        |        |        |        |
| 21  | BDA 30201 | Solid Mechanics III                   | 90%   | 97%   | 99%   |       |       |       |       |       |       |        |        |        |        |
| 22  | BDA 30301 | Thermodynamics II                     | 81%   | 99%   | 99%   |       |       |       |       |       |       |        |        |        |        |
| 23  | BDA 30401 | Manufacturing Technology              | 99%   | 99%   | 99%   |       |       |       |       |       |       |        |        |        |        |
| 24  | BDA 30501 | Heat Transfer                         | 99%   | 99%   | 99%   |       |       |       |       |       |       |        |        |        |        |
| 25  | BDA 30601 | Control Engineering                   | 99%   | 99%   | 100%  |       |       |       |       |       |       |        |        |        |        |
| 26  | BDA 30701 | Mechanical Engineering Design         | 74%   | 99%   | 100%  |       |       |       |       |       |       |        |        |        |        |
| 27  | BDA 30801 | Engineering Laboratory V              | 99%   | 99%   | 99%   |       |       |       |       |       |       |        |        |        |        |
| 28  | BDA 30901 | Engineering Laboratory VI             | 79%   | 99%   | 99%   | 99%   |       |       |       |       |       |        |        |        |        |
| 29  | BDA 31001 | Industrial Training                   | 99%   | 99%   | 100%  |       |       |       |       |       |       |        |        |        |        |
| 30  | BDA 40101 | Industrial Engineering                | 99%   | 99%   | 100%  |       |       |       |       |       |       |        |        |        |        |
| 31  | BDA 40201 | Engineering Design                    | 100%  | 100%  |       |       |       |       |       |       |       |        |        |        |        |
| 32  | BDA 40301 | Finite Element Method                 | 99%   | 99%   | 99%   |       |       |       |       |       |       |        |        |        |        |
| 33  | BDA 40401 | Noise and Vibration                   | 99%   | 99%   | 99%   |       |       |       |       |       |       |        |        |        |        |
| 34  | BDA 40501 | Bachelor Degree Project I             | 99%   | 99%   | 99%   |       |       |       |       |       |       |        |        |        |        |
| 35  | BDA 40601 | Bachelor Degree Project II            | 99%   | 99%   | 99%   |       |       |       |       |       |       |        |        |        |        |
| 36  | BDA 40701 | Elective I                            | 93%   | 99%   | 100%  |       |       |       |       |       |       |        |        |        |        |
| 37  | BDA 40801 | Elective II                           | 99%   | 99%   | 100%  |       |       |       |       |       |       |        |        |        |        |
| 38  | BDA 40901 | Elective III                          | 99%   | 99%   | 100%  |       |       |       |       |       |       |        |        |        |        |
| 39  | BDA 41001 | Management and Professional Ethics    | 99%   |       | 100%  |       |       |       |       |       |       |        |        |        |        |
| 40  | BDA 41101 | Engineering & Society                 | 99%   | 100%  |       |       |       |       |       |       |       |        |        |        |        |
| 41  | BDA 42001 | Entrepreneurship                      | 100%  | 100%  |       |       |       |       |       |       |       |        |        |        |        |
| 42  | BDA 42101 | Engineering Economics                 | 99%   | 99%   |       |       |       |       |       |       |       |        |        |        |        |
| 43  | BDA 42201 | Computer Programming                  | 99%   | 99%   | 100%  |       |       |       |       |       |       |        |        |        |        |

Total Responder: 56
Respondent Percentage (%): 6
Average Score (Student achievement) Results: 87.8
The attainment of PLOs will be assessed in continuous assessment including quizzes, assignments, projects and tests. The total mark of continuous assessment is 50% and remaining 50% are allocated for final examination marks for the courses. The marks from continuous assessment and final examination will contribute to the CLOs marks, based on the weightage that has been determined at the beginning of the semester. The contribution of each CLO to the particular PLO, depending on the weight dissemination, thus can be analysed. The PI of each CLO is set as 100% students get 40% marks and above. At course level, the individual PLO attainment of each course is measured based on the total percentage of students who get at least 40% score and above, as shown in Figure 3.

Once the CLOs assessments are completed for all courses, the respective PLO mapped to the CLO will be assessed. An example of cumulative CLO attainment that contribute to PLOs achievement for cohort 2010 is presented in Table 4.

3. Analysis and Evaluation of Programme Learning Outcomes Attainment
This section discusses the PLOs attainment results from both indirect and direct measurement approaches.

3.1. Analysis of PLOs Achievement by Indirect Assessment
(i) Industrial Survey
Figure 4 presents the analysis of the PLOs’ achievement through the industrial survey for cohort 2010. The survey indicated that employers confirmed good attainment of FKMP students’ in terms of different attributes, in relation to the different PLOs, as shown in the PLOs attainment of PLO 1 (Engineering Knowledge), PLO 2 (Modern Tool Usage), PLO 3 (Communication), PLO 5 (Individual & Team Work), PLO 6 (Lifelong Learning), PLO 8 (Ethics), PLO 11 (Problem Analysis), and PLO 13 (The Engineer and Society). It is thus indicating that more than 80% of the respondents agree that the students are noted as both good and excellent index for these PLOs.

(ii) Exit Survey
Error! Reference source not found.5 presents the alumni self-perception of competence at time of graduation, for graduates of cohort 2010. As shown in Figure 5, the PIs for PLO 3 (Communication), PLO 5 (Individual and Team Work), PLO 6 (Lifelong Learning), PLO 8 (Ethics), PLO 9 (Project...
Management & Finance) and PLO 13 (The Engineer and Society) are achieved this cohort. Thus this implies that the alumni agree that the current PLOs are able to equip them with the skill needs at workplace.

3.2. Analysis of PLOs Achievement by Direct Assessment
The results of PLOs achievement by direct measurement for cohort 2010 are shown in Figure 6. It is clear that the percentage of courses from this cohort at every PLO which attained minimum 80% score. It is clear that all cohorts have attained the targeted PI.
3.3. Consolidation of PLOs Achievement from Indirect and Direct Assessment

Consolidation of PLOs achievement data is performed by integrating direct assessment data (represented by University) and indirect data (represented by Student Survey and Industry Survey). These data are plotted into sets of triangular diagrams based on the respective PLOs.

Figure 7 shows the triangulation diagrams for cohort 2010 of these aforementioned PLOs assessment methods. The red dot at the centre of each triangle is the reference point, which indicates balance agreement on the PLOs achievement between the university, industries and students. Meanwhile the blue dot indicates the result of consolidated data obtained from university assessment and, industry and student survey. If the blue dot coincides with the red dot, it shows that the PLOs achievement is satisfactory for the three parties. The consolidation analyses ratify that almost all PLOs are well attained by the students as both blue and red dots coincide well between them. For example, for PLO 5, 35.3%, 32.1% and 32.5% PLOs achievement from the perspective of university, student and industry are achieved, where the percentages are near to the ideal balance point, which is represented by 33.33%. Figure 7(g), (j) and (l) reveal that the perception of PLO7, PLO10 and PLO12 attainment by the industries and students is slightly low compared to the direct assessment data (university).
4. Conclusion
Through data consolidation, in whole, the analysis indicates that PLOs achievement of the BDD programme is agreeable between the three parties and indeed a rather balanced programme. However, at course level, the PLOs attainment of some courses can be further improved through some continual quality improvement (CQI) strategies. The Faculty monitors this concern through OBEsys and CEPAT. At the end of the semester, the respective lecturers have to identify the causes of underachievement and propose the potential action taken in OBEsys and CEPAT. The proposed CQI can be viewed by other lecturers in the coming semester, where necessary action can be taken.
References

[1] Engineering Programme Accreditation Manual 2012, Engineering Accreditation Council. This reference has two entries but the second one is not numbered (it uses the ‘Reference (no number)’ style.

[2] Breslow, L. (2007). Methods of Measuring Learning Outcomes and Value Added. Teaching and Learning Laboratory, Massachusetts Institute of Technology.

[3] Faculty of Mechanical and Manufacturing Engineering (2016). Universiti Tun Hussein Onn Malaysia, Course Profile Handbook V5.1.