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Open-Ended Laboratory: Comprehensive Course Evaluation Framework for Structural Engineering Laboratory

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ABSTRACT

Comprehensive course evaluation is important to provide better performance of teaching and learning assessment. In higher learning education for engineering laboratory subjects, the requirement of evaluation provides complicated criteria where it needs to fulfill Outcome-based Education, Open-ended Laboratory and Complex Engineering Problems. Previously, the laboratory course was conducted through fully guided assignments by using too many separate evaluation guidelines and rubrics; thus, it became difficult to keep track each assessment tool and openness level which led to complication and confusion to the students. A misunderstanding process on the mapping of the criteria always occurs which contributes to the misleading of domain evaluation for each course. Therefore, this study was developed to design a comprehensive course evaluation framework for open-ended laboratory subjects by using educational and accreditation guidelines. EAC, UHEK and OEL guidelines were referred to as a comprehensive reference in developing the teaching and learning mechanism for each course developed in UiTM. Six main stages from the gathering of course information to the development of comprehensive rubrics should be carefully defined to ensure holistic framework is provided in this study. It was found that the framework provides clear mapping of the three main criteria developed as guidelines for the evaluation process in engineering laboratory subject. Besides that, it gives an objective evaluation criterion that meets the difficulty level of the subject with respect to OBE, OEL and CEP. The framework is able to be implemented in all subjects either engineering or non-engineering by mapping each evaluation criteria based on the nature of the subjects.

Keywords: *criteria performance matric, complex engineering problems, comprehensive course evaluation, open-ended laboratory, outcome-based education*

INTRODUCTION

Structural Engineering Laboratory is a subject offered for Civil Engineering students either in diploma or bachelor degree level. This subject is offered as a compulsory subject to deliver the knowledge on structural engineering in two scopes which are light structure and heavy structure. Basically, this subject is known as the introduction subject that is important to emphasize civil engineering theory through laboratory which relates to structural engineering. Structural engineering is part of sub-discipline of civil engineering in which structural engineers are trained to design the 'bones and muscles' that

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create the form and shape of man-made structures for building and infrastructures. Basic theories applied in this subject are the stability, strength, rigidity and earthquake-susceptibility of built structures for buildings and non-building structures such as bridge, damn, water-tank and road. The structural designs are integrated with those of other designers such as architects and building service engineers who often supervise the construction of projects by contractors on site. Furthermore, the structural engineering theory is based upon applied physical laws and empirical knowledge of the structural performance of different materials and geometries. Structural engineering design uses a number of relatively simple structural concepts to build complex structural systems.

In the curriculum development for civil engineering program, this subject is known as a compulsory subject to be taken by students with the implementation of outcome-based education, open-ended laboratory and complex engineering problems. A comprehensive curriculum is important to ensure the sustainability of the course in terms of syllabus content and assessment that fulfill the need of Engineering Accreditation Council (EAC) and Washington Accord. Transparent criteria of assessment are important to be highlighted in engineering subject so that each of the course objectively meets the quality and is accepted by stakeholders involved in civil engineering field. Outcome-based Education approach embedded with Complex Engineering Problem through Open-ended Laboratory teaching and learning process is causing misinterpretation among the instructors in handling the whole course. Sometimes, separate evaluation guidelines were developed by instructors in the overall summative assessment whereby it should be adjusted or modified in every semester. Some of the courses provide so many rubrics that separate each assessment tool and openness level which causes complicated and confusing documentation of reference; therefore, it is required to have clear and readable rubrics for students and instructors during implementation (Noor, 2020). For example, in the previous assessment implemented in the laboratory course, every level of each assessment had a rubric for the lecturer to use in the scoring of the assessments which did not follow the actual weightage for each domain criteria but the percentage domain solely. Although it looks like a well-organized assessment system, it does not reflect fairness and transparency in grading for each student. Therefore, assessment is very important for the students to acquire knowledge and it plays a crucial role in the process of learning connecting students to new knowledge using their current abilities (Tosuncuoglu, 2018).

Enhancement of the syllabus requirement related to learning outcomes in laboratory works particularly in engineering practices, testing, and learning via hands-on by instruction may not sufficient (Bolong et al., 2014). In education servicing, a university is required to accept notably changes regarding their approach or methodology to produce graduates that fulfill industry’s current demands. This will help higher learning institutions become competitive for the betterment of our nation (Awang Ali, 2016). Baharom et al. (2015) also proposed further implementation of assessment method by relating psychomotor and cognitive performance using quadrant analysis to emphasize better performance of student in laboratory work. Areekkuzhiyil (2021) stated that assessment is determined as a critical component of education process as it should be practiced with extreme care and vigilance. Educational practitioners must be very cautious of the issues involved in the assessment practices in classrooms and must take steps to continuously improve its quality and modernize the practice. Furthermore, a well-designed rubric can help students identify their strengths and weaknesses and be more objective about their own quality of work (Chowdhury, 2018).

The Program Outcomes (POs) and Program Educational Outcomes (PEOs) are mapped using the guidelines set by the Engineering Council to those required by the Engineering Accreditation Council (EAC), Malaysia (EAC, 2020). The outcome of the mapping exercise was used to formulate an anonymous online questionnaire survey as a measure of the PEOs' attainment (Tshai et al., 2014). As an implementation of preparing final examination question at Universiti Teknologi MARA (UiTM), the master Examination Specification Table (EST) is used as the main reference to prepare the questions with flexibility in terms of marks, types of question and difficulty levels. This approach has been implemented to all programs which provide an effective examination management system to produce quality assessment tools. Therefore, this study was conducted to design a comprehensive course evaluation framework for open-ended laboratory subjects with respect to outcome-based education and complex engineering attributes.

LITERATURE REVIEW

Unleashing the potential of quality continuous improvement in teaching and learning is important as an appreciation of the difference between assessment and evaluation. Assessment has frequently developed confusion and confounding evaluation due to different perspectives. Before Open-ended Laboratory was applied to the laboratory subjects, the approach was conducted using fully guided assessments. The previous method of teaching laboratory courses was described as the traditional method and students followed everything that had been instructed to them. They conducted the experiments; yet they had to stick to the fully-guided manual. They did not have the freedom to fully participate in the laboratory activities. Ideally, the purpose of evaluation is to judge the quality of a performance or work product against a standard while the fundamental of assessment is to help a student to expand the effort by providing quality feedback that will enhance the student's future performance (Yambi & Yambi, 2020). In teaching and learning, assessment is defined as a procedure applied by instructors and students during instruction through which lecturers provide necessary feedbacks to modify on-going learning and teaching to develop learners' attainment of planned instructional aims (Robinowitz, 2010). According to Popham (2008), assessment is defined as an intended procedure in which evidence of learners' status is utilized by educators to adjust their on-going instructional processes or applied by learners to change their present instructional strategies for better teaching and learning. Assessment intends to improve learning and it is important to reduce the gap between students' present instructional situation and their target learning objectives (Heritage, 2012). In an overall view, assessing students' performances is a part of recognizing and gathering information, receiving feedback, analysing and modifying the teaching and learning processes throughout the semester. The main goal, thus, is to overcome barriers to learning and for the purpose of quality improvement. Assessment is then used to interpret the performances of students, develop learning, and action to improve teaching approach (Aouine, 2011; Ghahderijani et al., 2021).

In engineering educational system, preparing engineers to be leaders in the development of a nation requires them to be trained with various industrial skills such as communication, management, law, politics and environment. Furthermore, the engineering education model developed for Malaysia is expected to be capable of achieving global recognition and accreditation for excellence in engineering practice as well as educating future leaders which includes strengthening the scientific and professional competency base of the engineering studies, and the inclusion of various humanistic, industrial, practical, global and strategic skills (Johari et al., 2002). Therefore, to be recognized by global organization and industries, three main components should be embedded in the evaluation of the course offered which are outcome-based education, complex engineering attributes and open-ended approaches for laboratory subjects (Karim & Khoo, 2013; Isa et al., 2021; Haron et al., 2013).

Outcome-based Education for Engineering

Outcome-based Education (OBE) is defined as a comprehensive approach to organizing and operating a curriculum that is focused on and defined by the successful demonstrations of learning sought from each learner and the adoption of OBE in engineering education is the compelling necessity (Spady, 1993; Syeed et al., 2021). OBE emphasises on two main components in terms of student achievement in an academic programme which are the Programme Outcomes (POs) that is measured at the point of graduation, and the Programme Educational Objectives (PEOs) that is assessed over a longer period of time after graduation (Tshai et al., 2014). Furthermore, Outcome-based Education (OBE) emphasises two main components in terms of student achievement in an academic programme. One is the Programme Outcomes (POs) which is measured at the point of graduation, while the other is the Programme Educational Objectives (PEOs) which is assessed over a longer period of time (around 4 to 5 years) after graduation (Tshai et al., 2014).

In the latter approach in outcome-based education, fresh engineering graduates are assessed by potential employers based on skills and competence needed for the required job, rather than mere knowledge acquired during their formal education. Learning Outcomes provides verifiable statements for graduates who are expected to know, understand and be able to apply during work. Furthermore, learning outcomes also focus on what the learner has achieved and can demonstrate at the end of the learning activity rather than the intention of the lecturers. The student-centered approach is what makes the difference between the objective and the learning outcome of a teaching activity (Rao, 2003). In engineering courses, the implementation of OBE has developed an overall and holistic approach recognised by global organisations that consist of Course Outcomes at the course level which is mapped to Program Outcome at the program level (Alias & Bhakari, 2008; Ismail et al., 2010).

Open-Ended Laboratory

In the Open-ended Laboratory (OEL) style, the problem that is brought into knowledge provides multiple solutions and specific methods in solving the problem which gives opportunity to students in finding the correct theory to be implemented in practical (Primer, 2006; Land, 2000). Hence, this is driving the laboratory course to become more explorative and interesting in the sense that students use their own initiative and creativity to design their own experiments (Chiu & Chiu, 2004). Due to the nature of OEL, students can improve their learning ability (Berg et al., 2003), encourage their individual creativity (Chiu & Chiu, 2004), gain self-confidence (Brickman, 2009) and feel the design environment for real industry outside the academic world (Domin, 2007). For this reason, most of the laboratory experimental works are done in many scientific areas which currently embrace open-ended working situations (Domin, 2007; Caccavo, 2011; Norliza et al., 2010; Tsarpalis & Gorezi, 2005). OEL is also linked to authentic student achievement; thus, students can actively experience the feeling of practiced professionals (Wright, 1996). One important aspect of OEL is that students need high self-motivation and according to Berg et al. (2003), students with weaker attitudes need more support to meet the challenge of OEL. The OEL assessment is separated into common test, practical test, and group and individual report writing. This completes all the domains of cognitive, psychomotor and affective in Bloom’s Taxonomy (Ali et al., 2014; Narita et al., 2014). Laboratory activities provided in the course are based on the level of openness that is determined by the instructors and categorized into levels of 0, 1, 2 and 3 (Ali et al., 2016).

According to the Engineering Accreditation Council & Board of Engineer Malaysia (2020), in order to ensure a minimum quality of engineering programs, it is necessary to provide adequate exposure to laboratory work and professional engineering practice. The laboratory exercises should be open-ended and able to address the relevant course outcomes and program outcomes, complementing the engineering theory. The assessments must integrate both theory and practice through these open-ended laboratory exercises. It is recommended that students work in teams with a maximum of five members per group. Therefore, to establish program outcomes (POs) for each laboratory course, the faculty curriculum unit has set percentage of domain focus on addressing all three domains: cognitive, affective, and psychomotor as shown in Table 1.

Table 1: Percentage of Domain

Domain	Proportion
Cognitive	20%
Psychomotor	60%
Affective	20%

Table 2 shows the assessment method and criteria for each domain in general for all laboratory courses. The cognitive domain is assessed through one written test at the end of the semester. However, the written test or final assessment can be replaced with one assignment where ever necessary. As for the psychomotor domain, it is evaluated through practical test. Practical tests are conducted twice, with each contributing to 20% of the final marks. Meanwhile, the affective domain, on the other hand, is evaluated through lab observation during students' lab works.

Table 2: Assessment Method and Criteria Based on Domain

Domain	Assessment Method	Assessment Criteria	Assessment Proportion
Cognitive (PO2)	Written Test/ Assignment	Answer Scheme/ Rubric	20%
Psychomotor (PO5)	Practical Test 1 Practical Test 2 Lab Observation	Rubric Rubric Rubric	20% 20% 20%
Affective (PO9/PO10)	Lab Observation	Rubric	20%

For laboratory courses, the criteria that cover students' preparedness to carry out experiments are measured from the laboratory work. Students are observed throughout the laboratory work on how to conduct assigned lab work according to the level of openness. To reflect the grading transparency for each student, the faculty curriculum unit also suggested the percentage of marks distribution for lab observation with the OEL implementation (see Table 3). Each mark distribution is based on the percentage degree of openness. OEL Level 3 has a higher mark distribution than other OEL levels because students are required to conduct and solve the experiment fully independently. However, the overall total marks proportions must follow the assessment proportion for the domain.

Table 3: Suggested Percentage of Mark Distribution on Lab Observation based on OEL Implementation

Domain	Percentage of Mark Distribution (%)				
	OEL Level 0	OEL Level 1	OEL Level 2	OEL Level 3	Total
Psychomotor (PO5)	-	5	7	8	20
Affective (PO9/PO10)	-	5	7	8	20

Complex Engineering Problems

Complex Engineering Problems (CEP) is a component that consists of engineering problems (WP), knowledge profile (WK) and complex engineering activities (CEA). Complex engineering problem solving is emphasized in the International Engineering Alliance's (IEA) programme outcomes (IEA, 2013) and the Engineering Accreditation Council, Malaysia's (EAC) accreditation standard (EAC, 2020). Programme outcomes (POs) are the attributes that reflect the student skills expected to be acquired upon graduation. The Engineering Accreditation Council (EAC) under Board of Engineer Malaysia requires 12 POs with CEP and knowledge profiles to be incorporated in engineering programmes. Despite considerable research on outcome-based education (OBE), the implementation with regard to the PO attributes and domains incorporating CEP characteristics is still questionable and vaguely implemented by the programs (Isa et al., 2021). In designing the laboratory assessment for the current syllabus, CEP must be considered accordingly. The complex engineering problem is embedded in selected assessments of each course following the percentages as shown in Table 4. The complex problem question or assessment should be designed to meet the higher domain level, and it is recommended to be at level 4 and above.

Table 4: Percentage of Complex Engineering Problem

Year 1	Year 2	Year 3	Year 4
5 – 10%	10 – 15%	15 – 20%	20 – 25%

METHODOLOGY

A qualitative analysis was conducted in this study to examine the problems in the evaluation process of this subject. Figure 1 shows the overall process of development of a comprehensive course evaluation framework for Structural Engineering Laboratory. The overall stages involved the identification of problems, classification of attributes, analysis of attributes and development of comprehensive assessment.

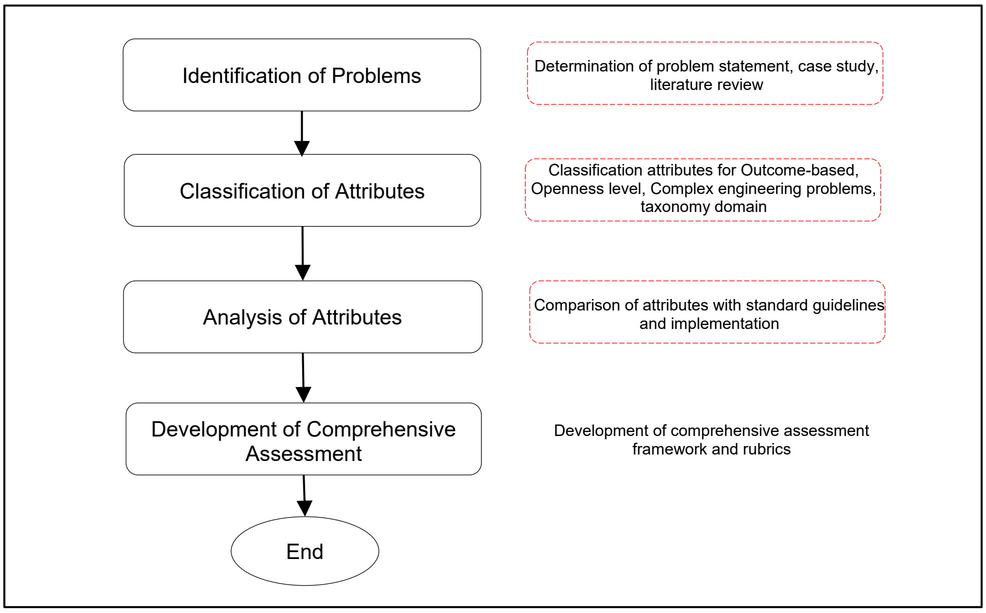

Figure 1: Methodology Framework

Identification of problems

Identification of problems involved identifying the problem statement, case study and literature review. In this study, the problem was identified based on field situation in teaching and learning of Structural Engineering Laboratory (CES511) for Bachelor of Engineering (Hons) Civil (Infrastructure). The problems were identified mainly related to assessment method which found that multiple assessment was using multiple rubrics. The problems were classified based on theme which included assessment attributed involved outcome-based, openness level, complex engineering problems and taxonomy domain.

Classification and analysis of attributes

The analysis was divided into four main attributes which are outcome-based, openness level, taxonomy domain, and outcome-based related to course outcomes and program outcome. The current implementation for each attribute was examined to define the overall miscellaneous of the assessment. The attributes were analysed to determine each parameter involved in the assessment process. In outcome-based, the course outcome and program outcome implemented were identified and aligned with EAC guidelines 2021. The openness level for this course was identified by mapping the percentage of openness with OEL guidelines. The CEP was identified to be assessed in the current implementation and the total percentage was calculated. All taxonomy domains which included cognitive, psychomotor, and affective difficulties level were determined and calculated for the current implementation and mapping of UHEK guidelines. The analysis was done separately for each attribute. A comparison of each attribute was made by using standard implementation in guidelines to ensure that it was developed using the correct constructive alignment and it was mapped towards each other. Global specification table for the assessments was developed to map all assessments so that each attribute contributed significantly as shown in Table 5.

Table 5: Structural Engineering Laboratory (CES511) Assessment Analysis

Course Assessment Plan (CAP)				Marks				TOTAL
				20	60		20	
Level	No. of Lab	Credit Hour	%	Cognitive	Psychomotor (PT1 & PT 2)	Psychomotor (Observation)	Affective	
OEL 1	5	6	42	8	22	4	8	**43**
OEL 2	4	4	33	7	18	1	7	**32**
OEL 3	3	10	25	5	0	15	5	**25**
Total	**12**	**20**	**100**	**20**	**40**	**20**	**20**	**100**
				100				

Development Of Comprehensive Course Evaluation Framework For Structural Engineering Laboratory

The Comprehensive Course Evaluation Framework (CCEF) was developed to provide effective assessment guideline for Structural Engineering Laboratory (CES511) Course offered in Bachelor of Engineering (Hons) Civil (Infrastructure) at Civil Engineering Studies, College of Engineering, Universiti Teknologi MARA as shown in Figure 2. CES511 is a compulsory subject for the programme which is enrolled by third-year students in semester five with 1 credit hour. This course is also known as stand-alone laboratory subject that consists of two main areas which are light structure and heavy structure. Figure 2 shows the comprehensive evaluation framework for open-ended laboratory that is implemented to provide holistic assessment. The framework is developed based on three (3) main components in laboratory course which are OBE, CEP, and OEL. In overall, the framework is divided into six (6) main stages which are Stage 1: Course Information, Stage 2: Open-Ended Level, Stage 3: Outcome-Based Education, Stage 4: Complex Engineering, Stage 5: Rubric Development, and Stage 6: Current Assessment Table Development. Table 6 shows the details of Structural Engineering Laboratory course that explains the course information, course outcomes, program outcomes, taxonomy domain, complex engineering attributes, and openness level as part of the information needed in Stage 1. The total distribution marks for each openness level is calculated based on the number of laboratory experiments in the syllabus. Hence, the information should be accurately determined by following specific guidelines of Course Outcomes and Program Outcomes, difficulties level for each taxonomy domain, complex engineering problems based on Washington Accord (WA) and openness level for the laboratory subject.

Table 6: Structural Engineering Laboratory (CES511) Course Details

Information	Description
Credit hour	1
Semester	5 (3 years)
Course outcomes	CO1 – Analyse results of the experimental work and theoretical solutions to validate findings in providing justifiable conclusion to solve structural engineering problems CO2 – Organize laboratory work on structural elements and materials CO3 – Conduct and perform experiments effectively as an individual and as a member in a team
Program outcomes	PO2 – Ability to identify, formulate, research literature and analyse complex civil engineering problems in reaching substantiated conclusions using principles of mathematics, natural sciences and engineering knowledge. PO5 – Ability to utilise appropriate techniques, resources and modern engineering and IT tools in predicting and modelling of complex civil engineering problems with an understanding of the limitations. PO9 – Ability to function effectively as an individual, and as a member or leader in diverse teams and in multi-disciplinary settings.
Taxonomy domain	Cognitive: C1 to C4 Affective: A1 to A4 Psychomotor: P1 to P5
Complex engineering problems	WP 1, WP 5, WP 7, WK 3
Openness level	Level 1: 42 % Level 2: 33 % Level 3: 25 %

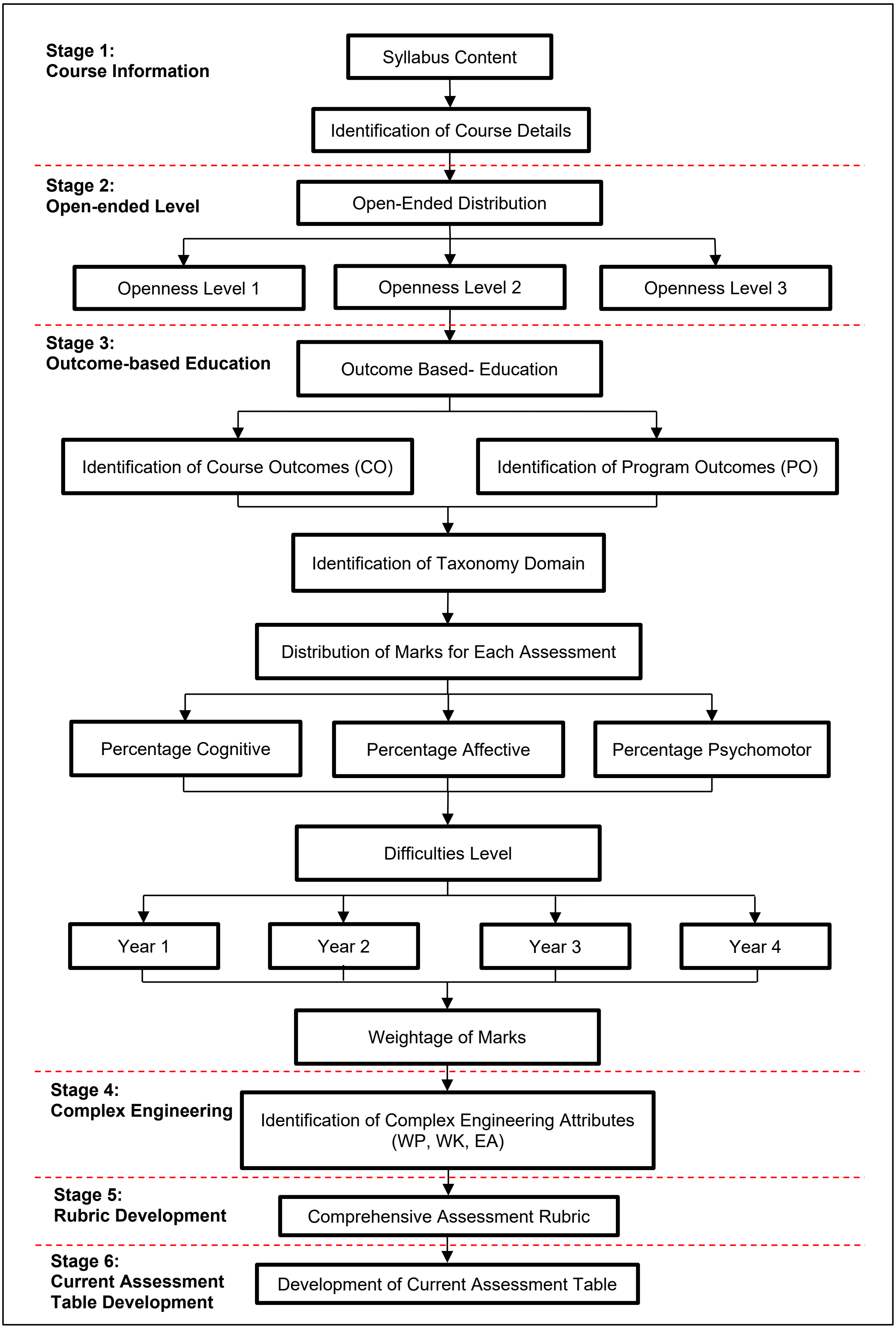

Figure 2: Comprehensive Evaluation Framework for Open-Ended Laboratory

In Stage 2, for OEL part, it is important to determine the percentage of openness level for the subject in order to distribute the topic based on each level. The degree of openness for open-ended laboratories should follow the level of openness. The percentage level of openness throughout the 4-year programme pursues the level of difficulty as set by Unit Hal Ehwal Kurikulum (UHEK), Bahagian Hal Ehwal Akademik (BHEA) dan Institut Kepimpinan dan Pembangunan (ILD), Universiti Teknologi MARA (UiTM) Shah Alam which was revised in January 2019. Table 7 shows the overall openness level design for 4-year degree program that explains the percentage range offered for laboratory course. In bachelor degree, the openness level offered is from Level 1 to Level 3 which shows the degree of difficulty in the course offered. In Year 4, it is divided into two which are 4a and 4b where 4a is for the courses other than project based subject and final year project.

Table 7: The Openness Level Percentage for Bachelor Degree Program Laboratory Course

Year	Level 0 (%)	Level 1 (%)	Level 2 (%)	Level 3 (%)
1	0	60 - 80	20 - 50	0 - 20
2	0	50 - 70	30 - 50	0 - 30
3	0	30 - 50	30 - 60	20 - 40
4a	0	10 - 30	30 - 60	40 - 60
4b	0	0	0	100

Source: UHEK (2019)

The distribution of marks based on openness level is shown in Table 8. The distribution of marks is distributed based on the percentage of openness level designed during the planning stage. It is important to ensure that the total assessment marks follow the Open-ended Laboratory Guidelines prepared by OEL Unit, Civil Engineering Studies, College of Engineering, UiTM Penang Branch in conjunction with the guidelines by UHEK. The distribution of marks should be prepared by resource person or course coordinator. The overall assessment should be designed as flexible for each semester as long as it follows the guidelines. Practically, the distribution of marks should follow the percentage of openness level offered for that particular subject and divide based on weightage for each domain. In this subject, it was decided that the distribution of marks is cognitive (20%), affective (20%) and psychomotor (60%) which comply with the guidelines. The overall marks based on OEL designed for this subject consists of OEL 1 (42%), OEL 2 (33%) and OEL 3 (25%) which comply with the percentage distribution as presented in Table 3. The development of rubrics is known as a thought of as a scaffold or pedagogy to support the development of evaluation in each course. There is extensive diversity of rubric practices (Dawson, 2015), some of which may better support the development of evaluative judgement for summative and formative use than others (Panadero & Jonsson, 2013).

Table 8: Distribution of Marks based on Open-ended Laboratory

Domain	CO:PO	Assessment Method	OEL 1	OEL 2	OEL 3	Total (OBE)
Cognitive	CO1:PO2	Report	8	7	5	20
Affective	CO3:PO9	Teamwork	8	7	5	20
Psychomotor	CO2:PO5	Practical Test	22	18	0	40
		Observation	4	1	15	20
Total (OEL)			**42**	**33**	**25**	**100**

In Stage 3, Outcome-based Education takes place in the determination of domain that is adopted for the course. In CES511, cognitive, affective and psychomotor are determined as the domain to be assessed in this course with specific percentage and degree of difficulties. Table 9 shows the overall OBE marks distribution for CES511 in terms of domain and degree of difficulties by following the guidelines provided by Unit Hal Ehwal Kurikulum (UHEK), Bahagian Hal Ehwal Akademik (BHEA) dan Institut Kepimpinan dan Pembangunan (ILD), Universiti Teknologi MARA (UiTM) Shah Alam. The assessment of each domain should be 100 percent by following the difficulty level. Furthermore, it is important to ensure that the percentage of each difficulty level for each domain follows the range that has been decided by UHEK in their guidelines.

Table 9: Outcome-based Education Mark Distribution

Domain	CO:PO	Method of Assessment	Difficulties Level (%)			Total
Cognitive	CO1:PO2		C1 – C2	C3 – C4	C5 – C6	
		Report	4 (20%)	16 (80%)	0	20 (100%)
Affective	CO3:PO9		A1 – A2	A3 – A4	A5	
		Teamwork	8 (40%)	12 (60%)	0	20 (100%)
Psychomotor	CO2:PO5		P1 – P2	P3 – P4	P5 – P7	
		Practical Test	8 (13.4%)	28 (46.7%)	4 (6.7%)	40 (66.8%)
		Observation	3.5 (5.8%)	12.25 (20.4)	4.25 (7%)	20 (33.2%)
Total Marks						**100**

In Stage 4, Complex Engineering Problem should be assigned for the whole subject. The implementation of CEP is determined with the alignment of WPs, WKs and WA as related to the course. For CES511, it was decided that three attributes of depth of knowledge (WP1), extent of applicable codes (WP5), and interdependence (WP7) are mapped to PO2 (problem analysis), PO5 (modern tool usage) and PO9 (individual and team work) which contributed to 6 percent as determined by center. In this subject, for OEL3 experiments, the preamble of the laboratory experiment is provided to the students. Students need to have fundamental knowledge on concrete (WP1:WK3), modify the concrete mix by adding steel fiber which is not mentioned in any standards for concrete design (WP5) and interpret interrelated results/data (compression, flexural testing and failure mode) to propose the viable solution (WP7). The mapping of CEP was also decided by Civil Engineering Studies, College of Engineering, UiTM Cawangan Pulau Pinang.

Comprehensive rubric for structural engineering laboratory assessment

The comprehensive rubric is a combination of all three elements which are outcome-based education, open-ended laboratory and complex engineering problem as shown in Stages 5 and 6 in Figure 1 that omitted previous practices using separated evaluation rubric (8 rubrics) and caused confusion to the students and instructors. A combination of all evaluation and assessment criteria in one rubric was found to be an effective guidance to students and instructors for each domain as it produced only three (3) rubrics for the overall evaluation. Consistent deployment of rubrics within a program or across an institution can represent a significant shift for all stakeholders which requires leadership from the top down to support the effort (Olson & Krysiak, 2021). The rubrics developed for this subject are used as the master rubrics that are referred to at every semester. Furthermore, the evaluation marks are also stated in the rubric which is the combination of each assessment marks, assessment tools and weightage of each assessment. Performance matrix scale is used in the rubric to differ the assessment marks based on each taxonomy domain either cognitive, psychomotor, and affective. The limitations of criteria that is used to evaluate each assessment tools should be determined to avoid so many criteria in each evaluation since the marks weightage will be very small and not significant for the evaluation.

Tables 10, 11 and 12 show the overall evaluation marks developed to build up the comprehensive rubric for CES511. In Cognitive domain, the assessment tool is divided into three main elements which are Laboratory Report 1, Laboratory Report 2 and Laboratory Report 3. Each laboratory report is divided into three main openness levels that are assigned for this subject which include Level 1, 2 and 3. In overall, there are 4 criteria evaluated for this domain which are planning, procedure, data analysis, and discussion and conclusion as stated in Table 10. However, in Openness Level 1, planning and procedure criteria are not evaluated due to the preamble and procedures provided in laboratory manual while for Openness Level 2, planning criteria is not evaluated. Furthermore, the assessment mark in Table 5 shows two columns for each assessment tool where it shows the total marks for the report are based on performance matrix scale 1 to 5 for each criterion while another column shows the weightage that will be contributed by each criterion for overall summative assessment.

Table 10: Evaluation Marks for Cognitive Domain

20	Level	Criteria	Lab Report 1		Lab Report 2		Lab Report 3	
			OEL 1		OEL 2		OEL 3	
CO1:PO2 (20%)	C1-C2	Planning					5	1
	C1-C2	Procedure			5	1	5	2
	C3-C4	Data analysis	5	4	5	3	5	1
	C3-C4	Discussion & conclusion	5	4	5	3	5	1
Total Marks			**10**	**8**	**15**	**7**	**20**	**5**

In Psychomotor Domain, the assessment tool is divided into two main elements which are Practical Test and Observation as shown in Table 11. In the evaluation of psychomotor domain, it is divided into two types of assessment which are practical test and observation. Practical test is used to evaluate student's performance after practical class through the examination without guidance from the instructor. Meanwhile, observation is used in the evaluation of psychomotor domain to evaluate the student's skills during the class and examine their understanding after the demonstration has been done by the instructor. The practical test is divided into two main tests which contribute 40 percent of total marks which are Practical Test 1 (22%) and Practical Test 2 (18%). The distribution of marks is based on the laboratory percentage for Openness Level 1 and Openness Level 2 in overall syllabus. Another 20 percent is contributed by observation which is divided into three assessments of Observation Openness Level 1 (4%), Observation Openness Level 2 (1%) and Openness Level 3 (15%). In Psychomotor Domain, the distribution of mark shows different calculations based on guidelines provided by OEL Unit, Civil Engineering Studies, College of Engineering, UiTMCPP. In overall, the percentage for each difficulty level should fulfill the guidelines of UHEK in total. In summative, Psychomotor Domain contributes 60 percent of the overall evaluation of this subject.

Table 11: Evaluation Marks for Psychomotor Domain

60	Level	Criteria	Prac. Test 1		Prac. Test 2		Observation		Observation		Observation	
			OEL 1		OEL 2		OEL 1		OEL 2		OEL 3	
CO2:PO5 (60%)	P1-P2	Handling	5	2	5	2	5	0.5	5	0.25	5	1
	PI-P2	Safety	5	2	5	2	5	0.5	5	0.25	5	1
	P3-P4	Method	5	15	5	13	5	2	5	0.25	5	10
	P5	Data Collection	5	3	5	1	5	1	5	0.25	5	3
Total Marks			**20**	**22**	**20**	**18**	**20**	**4**	**20**	**1**	**20**	**15**

In Affective Domain, the assessment tool is based on the teamwork of students during the teaching and learning process that is divided into four main criteria which are commitment, participation, responsibility and problem solving as shown in Table 12. In overall, the assessment of teamwork is divided into their openness level offered in this subject which contributes different weightage of summative marks based on percentage of syllabus for each level. It is the same as Cognitive and Psychomotor domains where the assessment marks are given based on performance matric scale of 1 to 5 in the rubric.

Table 12: Evaluation Marks for Affective Domain

20	Level	Criteria	Teamwork		Teamwork		Teamwork	
			OEL 1		OEL 2		OEL 3	
CO3:PO9 (20%)	A1-A2	Commitment	5	1	5	1	5	1
	A1-A2	Participation	5	2	5	2	5	1
	A3-A4	Responsibility	5	2	5	2	5	1
	A3-A4	Problem solving	5	3	5	2	5	2
Total Marks			**20**	**8**	**20**	**7**	**20**	**5**

Overall, the explanation of each rubric should follow the difficulty level for each domain, and it should be in the scale of 1 to 5. Furthermore, it is advisable to develop objective performance matrix for each domain to differ the specific criteria of scale 1 to 5. Subjective explanation in rubric performance matrix will cause misunderstanding among the students and lecturers to provide assessment answers and give accurate marks. Therefore, it is important to ensure that detailed and comprehensive rubrics are provided to students and instructors as proposed by Olson and Krysiak (2021) since rubrics transparently communicate what is essential in the learning activities and describe the characteristics of exemplary work. The implementation of well-written rubrics enables instructors and students to focus on the work's quality and promotes higher expectations.

CONCLUSION

In conclusion, comprehensive course evaluation is important to provide clear assessment of each course. This study found that the framework provides a clear process in the evaluation of CES511 subject without missing any criteria under outcome-based education, open-ended laboratory and complex engineering problems. Furthermore, as instructors or lecturers, it is beneficial to provide clear guidelines in developing the performance criteria matrix rubric that combines all elements in one master rubric without separating it based on openness level. As a student, the minimum number of assessment rubrics as references on the overall evaluation of the course will lead into easy understanding on teaching and learning process for the overall semester. The comprehensive evaluation course developed in this study is also applicable for any engineering and non-engineering course by understanding the important criteria and nature of each course so that it will not give complicated product at the end of the development process.

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AUTHORS' CONTRIBUTION

Hamid M.S.A. wrote the introduction, literature review, methodology section, and performed the development of framework in this study. He also wrote the data analysis, findings, and conclusion sections. Sakdun N.S.M. provided the content of comprehensive performance matrix rubric as resource person of CES511 course. All authors read and approved the final manuscript.

CONFLICT OF INTEREST DECLARATION

I/We certify that the article is the Authors' and Co-Authors' original work. The article has not received prior publication and is not under consideration for publication elsewhere. This research/manuscript has not been submitted for publication nor has it been published in whole or in part elsewhere. We testify to the fact that all Authors have contributed significantly to the work, validity and legitimacy of the data and its interpretation for submission to Jurnal Intelek.

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