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Issues and Challenges in Implementing Outcome Based Education in Engineering Education

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Abstract

In recent years, the implementation of outcome based education (OBE) has been much emphasized in developed and developing nations which led to becoming the focal point for educational reforms. In outcome based education, students are responsible for their own learning and the assessment of learning are based on the outcomes instead of the contents being taught. However, much criticism against the OBE has also been presented in various papers regarding the actual implementation of OBE. In this paper, we discussed the issues and challenges of implementing an outcome based education in engineering education particularly in Faculty of Engineering, UNIMAS, Malaysia.

1. Introduction

Outcome based education (OBE) is the latest paradigm shift sweeping the education system. The increasing need to produce more able and competitive learners for the globalized world has led to a reform in the education system whereby the learning is no longer a unilateral process but shifted its weight to be borne by the learners. The OBE itself is a recurring education reform model which is based on a student centered learning philosophy and focuses on the output (outcomes) instead of the input (taught) [1]. In contrast with traditional education, OBE puts much emphasis on the learning process being actively pursued and managed by the students themselves and the lecturers are only acting as facilitators in the students' quest for knowledge. Specific and clearly defined outcomes must be described to the students so that the students will be able to set their own expectations and means to achieve the desired outcomes. As such, the role of the lecturers is to guide and provide directions for the students to navigate their own learning. With the implementation of OBE, this has caused a revolution in the way the academia view the learning process and its relevant assessment. The assessments of student learning are no longer solely dependent on objective oriented exams. With OBE, the assessments methods of various skills, knowledge and attitudes become diverse and various learning pedagogies are introduced to ensure the achievement of the outcomes. Learning tools such as problem based learning, integrated design project, case studies are some of the methods utilized to assess subjective skills acquired by the students. The defined outcomes must be specific, measureable, achievable, realistic and time-based.

2. Outcome Based Education in Engineering Education

In engineering education, the outcome based approach has been mandated as compulsory for accreditation of an engineering programme for signatories of the Washington Accord. The Washington Accord is a mutual agreement of standards and qualifications criteria for engineering programmes in the signatory countries. In 2013, Malaysia has become a provisional member of Washington Accord together with United States, United

Kingdom, Australia, New Zealand, Ireland, Canada, Singapore, Russia, South Africa, Chinese Taipei, Hong Kong, Korea, Japan and Turkey. This means that the quality of the engineering graduates in Malaysia has to meet the internationally recognized benchmark for engineering education at par with the other nations. In Malaysia, the accreditation process is governed by the Engineering Accreditation Council (EAC) Malaysia which oversees the accreditation of engineering programmes offered by both public and private institutions. According to the mutually agreed standards and qualifications, the graduates from engineering programmes are expected to acquire a set of skills, knowledge and behaviours which is defined by Accreditation Board for Engineering and Technology (ABET) as Engineering Criteria 2000 (EC2000). In EAC Programme Accreditation Manual 2012, EC2000 equivalent skills, knowledge and behaviours are defined as the twelve Programme Outcomes (PO) stated as [2]:

a) Ability to apply knowledge of mathematics, science, engineering fundamentals and an engineering specialization to the solution of complex engineering problems;
b) Ability to identify, formulate, research literature and analyze complex engineering problems reaching substantiated conclusions using first principles of mathematics, natural sciences and engineering sciences;
c) Ability to design solutions for complex engineering problems and design systems, components or processes that meet specified needs with appropriate consideration for public health and safety, cultural, societal, and environmental considerations;
d) Ability to 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 conclusions;
e) Ability to create, select and apply appropriate techniques, resources and modern engineering and IT tools, including prediction and modeling, to complex engineering activities, with an understanding of the limitations;
f) Ability to apply reasoning informed by contextual knowledge to assess societal, health, safety, legal and cultural issues and the consequent responsibilities relevant to professional engineering practice;
g) Ability to understand the impact of professional engineering solutions in societal and environmental contexts and demonstrate knowledge of and need for sustainable development;
h) Ability to apply ethical principles and commit to professional ethics and responsibilities and norms of engineering practice
i) Ability to 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;
j) Ability to function effectively as an individual, and as a member or leader in diverse teams and in multi disciplinary settings;
k) Ability to recognize the need for, and have the preparations and ability to engage in independent and lifelong learning in the broadest context of technological change;
l) Ability to 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 manage projects and in multidisciplinary environments;

It is important to note that the achievement of the twelve Programme Outcomes must be attained by the graduates upon completion of the engineering programmes as an indicator for the implementation of outcome based approach. These twelve PO should also be directed mapped to Programme Educational Objectives (PEO) which are attributes expected to be acquired by the graduates between 3 – 5 years after graduation. Various inputs from internal and external stakeholders such as local government, industries, alumni, employers, advisory panels, students and parents are taken into consideration in developing the PEO for the programme. Overall, the outcome based education approach is to be implemented in the entire curricula to ensure the students attain a wider skill base in order to cope with the increasingly demanding globalized and complex world. According to Dudman and Wearne (2005), the engineering career is not solely focused on technological expertise but also covers a variety of managerial skills such as leadership skills, teamwork and project management [3]. The ability to work within multicultural and multinational workplace environments is also key issues for global mobility of an engineer. Baillie and Fitzgerald (2000) state that employers need employees with good critical, analysis and communication skills to relate innovative solutions within team based environment [4].

3. Issues and Challenges in Implementing OBE

The main problem with implementation of outcome based education is the broad definition of outcome based education itself. While it emphasizes the achievement of outcomes, this also refers to the achievement of learning outcomes (LO) for a particular course. The normal operation for an academic programme is to further map the courses LO to the PO in order to observe the accumulative sum of LO contributing to the achievement of PO. This correlative relationship is shown in the courses LO – PO mapping in Table 1. The concept of OBE also does not provide for any specific procedure or follow a single idea in achieving the outcomes which led to confusion to how best implement an OBE curricula [5]. The original concept of OBE should include the cyclic continual improvement with meaningful revision of teaching and learning pedagogies, delivery and assessment methods. The confusion is also extended during the construction of learning outcomes for a particular course.

Table 1: Courses LO – PO mapping

COURSES \ PROGRAMME OUTCOMES	a	b	c	d	e	f	g	h	i	j	k	l
Circuit Theory	X	X										
Electrical Engineering Technology	X	X										
Measurement and Instrumentation			X		X				X			
Structured Programming	X				X				X			
Engineering Mathematics I	X	X										
Analog Electronics	X	X										
Digital Electronics	X	X										
Analog and Digital Electronic Applications					X					X		X
Engineering Design Foundation		X			X					X		
Electrical Instrumentation	X	X										
Engineering Mathematics II	X	X										
Digital System Application		X			X				X			
Telecommunication Engineering Principles	X	X				X						
Software Engineering			X		X				X	X		
Signal & Systems	X	X			X							
Engineering Mathematics III	X	X										
Electronic Circuits	X	X			X							
Analog and Digital Communication Applications					X				X			
Computer System Operations	X	X									X	
Numerical Methods and Statistics	X	X										
Digital Signal Processing		X	X		X						X	
Control System Engineering		X	X	X								
Microprocessor		X	X		X							
Advance Electronic System Application					X				X			
Engineering Ethics						X		X				
Microelectronics		X	X		X							
Electromagnetic Theory	X	X	X									
Data and Computer Networking			X						X	X	X	
Optoelectronics		X								X		
Telecommunication Networks and Services				X		X	X					
Industrial Training						X	X	X	X	X	X	
VLSI Design			X		X	X	X					
Microwave and Antenna Technology		X			X					X		X
Optical Fiber Communication		X								X		
Final Year Project I				X	X			X	X			
Integrated Design Project I			X	X	X		X		X	X	X	X
Mobile and Wireless Communication			X	X		X				X		
Final Year Project II			X	X				X	X		X	
Integrated Design Project II			X		X	X	X	X	X	X	X	
Engineering Management									X	X		X

In traditional learning, the outcomes are mostly labelled as learning objectives which encourages the construction of LO being direct translation of course contents objectives [6]. In OBE, the outcomes should be significant achievements which stretches beyond the achievement of particular course contents and contributes to the behavioural attributes of the students. The ultimate aims of outcome based education in engineering education is to equip the undergraduates of an engineering program with the attributes necessary for them to transition themselves into professional career as a global engineer. However, these demand more effort for the academia to incorporate not only hard technical skills but also assessments of soft skills in the engineering curricula. The utilization of Bloom's Taxonomy Cognitive Domain, Psychomotor Domain and Affective Domain is implemented across all courses in each assessment inclusive of final exam, test, assignments and projects. Soft skills such as lifelong learning, project management, awareness on sustainability issues and social responsibilities as an engineer as well as engineering ethics are embedded in the assignments, case studies and projects.

Table 2: Bloom Taxonomy Cognitive, Affective and Psychomotor Domains

Cognitive: mental skills (Knowledge)
Affective: growth in feelings or emotional areas (Attitude)
Psychomotor: manual or physical skills (Skills)

C1	**Knowledge**: Recall data or information
C2	**Comprehension**: Comprehend the meaning, translation, interpretation of instructions and problems. State a problem in one's own words.
C3	**Application**: Use a concept in a new situation or unprompted use of an abstraction. Applies what was learned in the classroom into novel situations in the work place.
C4	**Analysis**: Separates material or concepts into component parts so that its organizational structure may be understood. Distinguishes between facts and inferences.
C5	**Synthesis**: Builds a structure or pattern from diverse elements. Put parts together to form a whole, with emphasis on creating a new meaning or structure.
C6	**Evaluation**: Make judgments about the value of ideas or materials.

A1	**Receiving Phenomena**: Awareness, willingness to hear, selected attention.
A2	**Responding to Phenomena**: Active participation on the part of the learners. Attends and reacts to a particular phenomenon. Learning outcomes may emphasize compliance in responding, willingness to respond, or satisfaction in responding (motivation).
A3	**Valuing**: The worth or value a person attaches to a particular object, phenomenon, or behavior. This ranges from simple acceptance to the more complex state of commitment. Valuing is based on the internalization of a set of specified values, while clues to these values are expressed in the learner's overt behavior and are often identifiable.
A4	**Organization**: Organizes values into priorities by contrasting different values, resolving conflicts between them, and creating an unique value system. The emphasis is on comparing, relating, and synthesizing values.
A5	**Internalizing values** (characterization): Has a value system that controls their behavior. The behavior is pervasive, consistent, predictable, and most importantly, characteristic of the learner. Instructional objectives are concerned with the student's general patterns of adjustment (personal, social, emotional).

P1	**Perception**: The ability to use sensory cues to guide motor activity. This ranges from sensory stimulation, through cue selection, to translation.
P2	**Set**: Readiness to act. It includes mental, physical, and emotional sets. These three sets are dispositions that predetermine a person's response to different situations (sometimes called mindsets).
P3	**Guided Response**: The early stages in learning a complex skill that includes imitation and trial and error. Adequacy of performance is achieved by practicing.
P4	**Mechanism**: This is the intermediate stage in learning a complex skill. Learned responses have become habitual and the movements can be performed with some confidence and proficiency
P5	**Complex Overt Response**: The skillful performance of motor acts that involve complex movement patterns. Proficiency is indicated by a quick, accurate, and highly coordinated performance, requiring a minimum of energy. This category includes performing without hesitation, and automatic performance.
P6	**Adaptation**: Skills are well developed and the individual can modify movement patterns to fit special requirements.
P7	**Origination**: Creating new movement patterns to fit a particular situation or specific problem. Learning outcomes emphasize creativity based upon highly developed skills.

However, the attainment of soft skills is difficult to measure. The assessment of soft skills must be conducted in several courses across the discipline to be proof of acquired skill. The lecturers limited knowledge on teaching and learning as well as assessment strategies may lead to a mass of unusable quantitative data instead of qualitative. In UNIMAS, these shortcomings was improved by offering Postgraduate Diploma in Teaching and Learning short programme for young lecturers, organized by Centre of Applied Learning and Multimedia UNIMAS. Consisting of eight modules, the PGD in Teaching and Learning introduces principles in education, basic learning pedagogies, deliveries and assessment methods to the academic staff. This PGD in Teaching and Learning span over one year and held during semester breaks.

Another problem faced by the faculty in implementing OBE is the perception of students and lecturers towards OBE. While OBE emphasizes on student centered learning, the actual implementation of OBE is still heavily reliant on instructors as presenters of knowledge. Apart from directly objective assessments such as final exams, tests, assignments and projects, indirect assessment such as surveys are conducted at the end of each course. There are two surveys conducted, one which evaluates the instructor's deliveries of the course by the students while the other evaluates the students own perceived understanding for the course. It is interesting to note that there are sometimes discrepancies and gap between the actual marks via objective assessment and students own perception on their understanding of the course and its contents. More so when the evaluation on the instructor's deliveries of the course is suggested to somehow influence the students' own perceived understanding of the course. The results shows a critical point in the students' perception of achieved LO and the possible influence of culture ingrained in the students. Results from the survey often give higher marks for deliveries and yet low on their own perceived understanding and this is averagely consistent in many LO evaluations. More in-depth study is suggested to look into the cultural factor of "humility" in Asian students whereby the students have the tendency to undervalue their own merits. In traditional learning, the lecturers are viewed as a providers and one which holds the answers to the questions while in OBE, the role of the lecturers is not to provide solutions but to guide them towards the discovery of the solutions. Thus, in OBE there is high expectation for extremely self reliant, resourceful and independent student characteristics which are often contradicted by its reality.

The implementation of OBE in engineering education also requires the integration of laboratory works which differentiates the engineering programme from many other disciplines. The laboratory works are essential tools to enhance the students understanding of theories in engineering and technology education. There are two types of instructional laboratories which are (i) physical laboratory and (ii) simulation laboratory. In traditional learning, the emphasis is on the content driven learning objectives which are the understanding of theories in laboratory works. However, in OBE this has changed into the acquiring of psychomotor skills in conducting the laboratory tools both in hands-on experiment or the fluency in the simulation tools. This process of transitioning from content to outcome based learning outcomes targeted dissimilar areas of students understanding and skills, and has reveal opportunities for vast improvement in the learning. Didactic approaches such as cases studies, problem based learning (PBL) and integrated design project (IDP) are also utilized in engineering OBE. The insufficiencies of traditional pedagogy to develop the skills of the engineering graduates have led to utilization of these approaches to reduce the distance between intended graduate attributes to actual performance in workplace. While critics dismiss case studies as no other than an exploratory tool, case studies have been widely applied in teaching and learning for the assessment of "soft" skills rather than "hard" technical skills. The development of analytical, evaluative and decision making skills are of extreme importance in engineering and managerial positions. The practice will also improve communication skills as case studies also emphasize on working towards a consensus while tolerating legitimate differences of opinions. In problem based learning, students take charge of what needs to be learned and how it should be learned, providing a platform for them to develop teamwork, problem solving and leadership skills. A well designed PBL course also introduces students to lifelong learning and thus satisfies many outcomes specified by EAC. IDP is a project which spans over two semesters that builds upon knowledge from previous multidisciplinary courses. IDP courses are the most recent requirement from EAC to be integrated into the curricula in order to prepare the students for the transition into engineers. These integrated design projects also incorporates inputs from the external stakeholders such as local governments and industries and designed to bring all aspects of an undergraduate learning experience into practice. Effective IDP is of high interest to the external stakeholders as the goal is to equip graduates with various engineering skills. The IDP is intended to develop the technical, planning, project management, leadership and teamwork, analysis and evaluative skills of the students.

In traditional education, the outcomes are focused on the content driven learning objectives which are determined by the lecturers without external input. In OBE, one of the criteria is the inclusion of inputs from various stakeholders such as the industry, local governments, employers, alumni, parents and students themselves. This is different from traditional learning models whereby the assessment of learning becomes an end. In OBE, the learning process is a continual quality improvement (CQI) process where the assessment of the learning outcomes provides information on how to improve the learning of the students. The analysis on the assessment of the students' performance is reported in the End-Semester-Report (ESR) for each course. A sample of the ESR for Electronic Circuit course is shown in Figure 1. The LO – PO and Bloom Taxonomy mapping for Electronic Circuit course is shown in Table 3

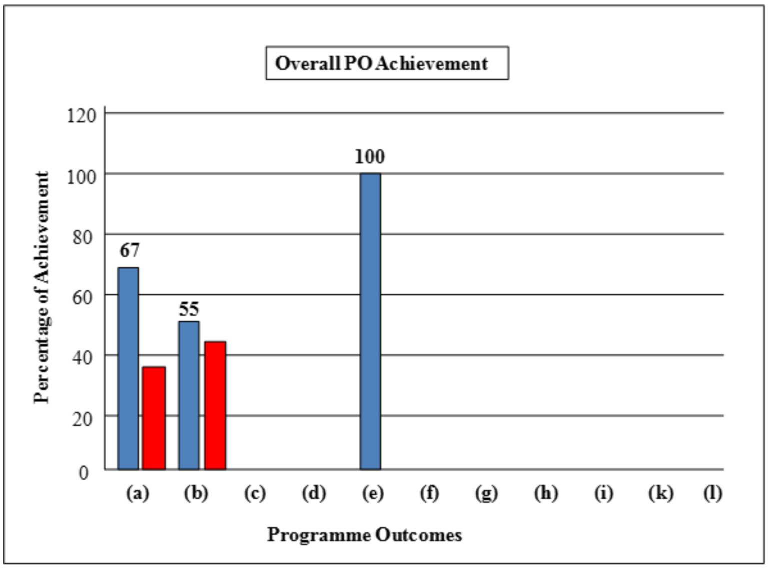

Figure 1(a): Overall PO achievement for Electronic Circuits course

	Final Exam				Test		Others			
	Q1	Q2	Q3	Q4	T1	T2	Project	Assignment	Quiz 1	Quiz 2
Full Marks	12.5%	12.5%	12.5%	12.5%	10%	10%	10%	10%	5%	5%
Strongly Achieved (75% - 100%)	14	10	8	16	12	26	82	78	71	80
Achieved (50% - 74%)	19	16	27	25	26	30	0	0	10	2
Not Achieved (25% - 49%)	24	24	30	31	32	22	0	4	0	0
Strongly Not Achieved (0% - 24%)	25	32	17	10	12	4	0	0	1	0

Figure 1(b): Breakdown analysis of marks distribution (no. of Students)

Table 3: LO – PO Mapping with Bloom Taxonomy

By the end of this course, the students should be able to:		PO Assessed	Bloom Taxonomy
LO1	Analyze basic circuit configurations to construct low and high frequency responses by applying BJT and FET small signal analysis.	PO (b)	C4
LO2	Solve basic electronic circuits such as op-amps, power amplifiers, linear digital ICs, feedbacks, oscillators and voltage regulators	PO (a)	C5
LO3	Utilize appropriate modern tools to design and generate electronic circuits (e.g. Pspice, Electronic Workbench, Multismetc)	PO (e)	P3

For Electronic Circuits course, the distribution of marks is given as Assignment (10%) which assesses PO (b), Project (10%) assesses PO (e), Quiz 1 (5%) assesses PO (b), Quiz 2 (5%) assesses PO (a), Test 1 (10%) assesses PO (b), Test 2 (10%) assesses PO (a), Final Exam (25%) assesses PO (b) and Final Exam (25%) assesses PO (a); for a total of 50% assessment for PO (b), 40% assessment for PO (a) and 10% assessment for PO (e). In the ESR, the achievement of individual assessment for each student is analyzed and accumulated to give an overall PO achievement statistics as shown in Figure 1(a). The overall PO achievement indicates the percentage of students achieving the PO (a) as 67%, PO (b) as 55% and PO (e) as 100%, out of a total of 82 students. The achievement of certain Programme Outcomes can be improved via analysis of marks distribution breakdown in Figure 1(b). A Continuous Quality Improvement (CQI) report must be submitted by the lecturer after each ESR analysis for comments and recommendations for improving the course.

The widespread technology of internet has revolutionized the way information is retrieved by the students. The immediate availability of information is changing the way students learn. According to a study by [6], a challenge in the implementation of OBE is the gap in the desired attributes and the actual attributes shown by the students whereby the common trend for the students is to first “google” the information and the solutions to given problems. The availability of vast information has led to the “summarizing” of data without truly polishing the students’ skills to defend, judge and criticize in their own words and also encourages the unwillingness of the students to exercise creative thinking skills necessary for the desired qualities. The upload of lecture materials in online systems such as Morpheus UNIMAS also caused the course materials to be accessible to the students at any time which may led the students as passive learners in actual lectures. Thus appropriate learning pedagogies such as group or team based approach is important to gauge students participation in a student centered learning. Other highlighted concerns are the difficulties to embed engineering ethics and social responsibilities as engineers. The current practice of ‘teaching’ ethics in traditional lectures is best avoided and be replaced by case studies. Ethical themes are also incorporated in the utilization of turnitin for the students to monitor their own work in avoiding plagiarism and reflective essays on policies and regulations related to engineering ethical practices. The implementation of OBE in engineering education should produce engineering graduates whom are active learners responsible for their own learning, creative and resourceful enough to independently seek solutions to engineering problems. For these attributes to be achieved, the students must first understand the value of their own learning process and have the ability to manage their own learning in achieving the desired outcomes.

4. Conclusion

The implementation of OBE in engineering education is a cyclic continuously improving model with the assessment of the outcomes is not the end but just the means to achieve the desired outcomes. Effective implementation of OBE gives opportunity for new ideas and challenges to develop an education model which resulted in improved learning outcomes. However, for OBE to be successfully adopted by a tertiary education, the academic staffs and the students must understand the objective of learning and the roles for both instructors and learners. Education in tertiary institution should not be a linear unilateral model but instead an active and engaging process which is a transition for the learners to prepare themselves for the workforce. In OBE, the end of the curricula does not signal the end of the learning process for the students but a continuum of lifelong learning skills developed in their tertiary education.

5. References

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