ASEAN Journal of Science and Engineering Education

Constructive Alignment Approach for Capstone Project with Industry Involvement: Case Study in Malaysia University

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A B S T R A C T S

A capstone project is a project-based learning course designed to bring aspects of an undergraduate student's experience. To have an effective capstone project, it is imperative to properly design the curriculum with involvement from the industry. To improve the performance of the capstone project course, we used the constructive alignment approach to design the curriculum. In constructive alignment, we mapped the intended learning outcomes, the assessment tasks and the teaching/learning activities interchangeably with each other. Experiments were conducted with students enrolled in the capstone project courses in our university from February 2016 to May 2017. The result shows that the new design was able to improve the attainment scores for both learning outcomes and program outcomes. This improvement was also in line with marks by industry experts indicating good potential.

A R T I C L E I N F O

1. INTRODUCTION

According to Ernst and Yong Report, most of the university models in Australia will be impractical over the next 10 to 15 years. These are caused by five emerging factors, namely: 1) Democratisation of knowledge and access, 2) Contestability of markets and funding, 3) Digital technologies, 4) Global mobility and 5) Integration with industry. To survive, the current university model should evolve and change (Ernst and Young, 2012). In the Horizon report, experts agreed that to keep being practical, universities need to rethink on how they work.

Project-based learning (PBL) is a student-driven, teacher-facilitated approach to learning which imitated industry. In PBL, active learning is encouraged and enforced. Students develop their own questions and are guided in their work under the teacher's or other expert's supervision (Bell, 2010). In relation to engineering education, according to Mills and Treagust, project-based learning is the best way to satisfy industry need without sacrificing knowledge of engineering fundamentals (Mills and Treagust, 2003). Due to the nature of the active learning embedded in PBL, Bell reported that project-based learning will encourage the student to be self-reliant (Bell, 2010). PBL promotes and encourages students to be able to self-learn and self-assess their own work. In another report, Boss, Krauss, and Conery reckon that with project-based learning, students are able to implement their knowledge to solve real-world problem (Boss *et al.,* 2007).

Different than vocational institutional (Rosina *et al.,*2021), the capstone project is an example of project-based learning found in university which closely related with industry project. A capstone project is a unique student course as students work largely in self-directed ways and are expected to embark on significant assessment tasks without structured support. Effective capstone projects are of high interest to employers of graduates, who rely on them to equip graduates with the knowledge necessary to bring success to their enterprises (Allan and Chisholm, 2008; Maleki, 2009). According to a research, meeting the needs of various stakeholders such as industry is essential in developing a capstone project (Todd and Magleby, 2005).

Ward looked at the world's top-ranked engineering universities to find the common element of the capstone projects which is considered as proven best practices (Ward, 2013). In his report, he found that in these universities, the capstone projects are 1) having prerequisite courses, which focus on problem-based learning, 2) group work, 3) based on design-build-test model, 4) involving industries and 5) assessed sequentially (related with component marking). These are in line with aspects of project-based learning reported by Helle *et al.,* (2006). In the report, they found that project-based learning; 1) aims to find a solution of problem (set by industries, teachers or students themselves), 2) initiated by group of students with a variety of educational activities, 3) results in an end product (a working model), 4) performed on a considerable length of time and 5) has teaching staff or industry experts as its supervisor which acts in an advisory role – initiation, conduct and conclusion. Taking these into consideration, it is imperative to design and develop a curriculum map for a capstone project which interrelates with all these factors.

In this report, we explain and present our thought process when developing the curriculum map for a capstone project course. In the design, we outline the course with the external factors /relationship such as the programme it resides in, including the programme level-intended learning outcomes. More importantly, the curriculum map needs to outline the internal relationships within the course in a manner consistent with the aspects of good curriculum design and assessment.

2. APPROACH

Curriculum mapping is the expression of educational ideas in practice, including all the students' planned learning experiences as described as 1) course aims and purpose, 2) course description, summarising: intended learning outcomes, teaching and learning activities, assessment tasks, contents, prerequisites and co-requisites, 3) the role of the course relative to the rest of programme especially the alignment with programme intended learning outcomes and 4) the alignment of all elements to higher order requirements such as Government requirements, university requirement, and association accreditation standards.

2.1.   Alignment with higher order requirements

Since 2013, the university introduced a new set of programme outcomes which was developed to meet multiple accreditation requirements of the Engineering Accreditation Council, Malaysia (EAC) (Engineering Accreditation Council, 2012), the Malaysian Qualification Framework (MQF), the Malaysia 7 Soft Skill and the Washington Accord Graduate Engineering Attributes. As part of regulation governed by the Malaysia Engineering Accreditation Council (EAC), the Faculty have taken immediate action to ensure that new programme outcomes are compatible and can be interrelated with twelve (12) EAC Programme Outcomes (EAC POs).

In Electronic and Electrical Engineering, the university come out with 12 Programme Outcomes (POs) as follows (SEGi University, 2016),

PO 1. Engineering Knowledge - Apply knowledge of mathematics, science, engineering fundamentals and an engineering specialization to the solution of complex engineering problems;

PO 2. Problem Analysis - Identify, formulate, research literature and analyze complex engineering problems reaching substantiated conclusions using first principles of mathematics, natural sciences and engineering sciences;

PO 3. Development of Solutions - 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;

PO 4. Investigation - 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;

PO 5. Modern Tool Usage - 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;

PO 6. The Engineer and Society - Apply reasoning informed by contextual knowledge to assess societal, health, safety, legal and cultural issues and the consequent responsibilities relevant to professional engineering practice;

 PO 7. Environment and Sustainability - Understand the impact of professional engineering solutions in societal and environmental contexts and demonstrate knowledge of and need for sustainable development;

PO 8. Ethics - Apply ethical principles and commit to professional ethics and responsibilities and norms of engineering practice;

PO 9. Communication - 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;

PO 10. Individual and Team Work - 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;

PO 11. Life-long Learning - Recognize the need for, and have the preparation and ability to engage in independent and life-long learning in the broadest context of technological change.

PO 12. Project Management and Finance - 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.

The programme outcomes are denoted as PO 1 – PO 12 and will be set as ground rules for the development of every course Intended Learning Outcomes (ILOs) including capstone project course. Setting during the department meeting and agreed by the faculty, we map the capstone project ILOs to five (5) POs which are PO 3 Development of Solutions, PO 4 Investigation, PO 9 Communication, PO 10 Individual and Team Work and PO 12 Project Management and Finance.

Dolence commented that in designing curriculum, it must be well design. The curriculum design should have a deliberate process of determining how the teaching and learning will be designed, developed and executed. He proposed a framework in curriculum design which have seven interrelated and interlocking components (Dolence, 2004) (which are learning populations, learning objectives, learning providers, learning theory and methods, curriculum architecture, curriculum configuration and learner services.) We found this approach however are too complex to be executed in our module since the seven component must be assessed objectively and interlocked. Levander and Mikkola proposed a conceptual tool, core curriculum analysis in designing curriculum. A core curriculum describes the knowledge and skills to be taught and learnt in a particular course or a degree programme (Levander and Mikkola, 2009). The approach however did not explain on the learning activities. Eustrom suggested that curriculum design is defined as projection of learning outcomes and its associated learning experience. The process begins by setting the expected learning outcomes and examining the pre-existing learning environment including factors such as national accreditation standards, university rules and programme (Crawley, Malmqvist, Östlund, and Brodeur, 2014). Biggs extended this idea and proposed a 'constructive alignment' approach that combine all components of the teaching system so that they are properly aligned with one another. In his proposed approach, the intended learning outcomes, teaching methods and assessment are listed as parts of teaching systems and they need to be aligned with learning activities. Looking as these different approaches, we believe that the constructive alignment are the most compatible to improve our capstone project module.

2.2. Constructive alignment of capstone project

"*Constructive alignment (CA) is a design for teaching in which what it is intended students should learn, and how they should express their learning, is clearly stated before teaching takes place. Teaching is then designed to engage students in learning activities that optimize their chances of achieving those outcomes, and assessment tasks are designed to enable clear judgments as to how well those outcomes have been attained*" (Biggs and Tang, 2011).

The general operational framework for CA is as follows; 1) Explain the intended learning outcomes (ILOs) of the capstone project course, using one verb for each outcome. 2) Design

teaching/learning activities (TLAs) which compel students to engage each verb defined in ILO. This will ensure that the activity defined in ILO is practiced, 3) Use assessment tasks (ATs) which also contain that verb to judge how well students' performances (using rubrics detailing the predetermined criteria), and 4) Transform these judgments into final grades.

Table 1 shows the mapping between the ILOs of capstone project with the Electronic and Electrical Engineering POs.

Figure 1 shows the correlation between ILOs, TLAs, and ATs in CA framework. As shown, ILOs, TLAs, and ATs are aligned and inter-dependent.

The pre-requisite of the capstone project is that students must pass the embedded computing system course before taking this course. In the embedded computing course, students are trained to find and develop a solution of an engineering problem.

The relationship between the teaching and learning activities (TLAs), assessment tasks (ATs), and intended learning outcomes (ILOs) of the capstone project is shown in **Table 2.**

The capstone project course is comprised of a three-hour lecture component and a three-hour lab component per week. The topics for the lecturer are case studies and theory on research methodology and experiment design.

Cooperative learning, project-based learning, and the use of simulations are implemented in this unit delivery. These learning activities require students to do meaningful learning activities and think about what they are doing which are emphasized on lab sessions. The core learning process is based on student activity and engagement in the learning process (Prince, 2004). In this approach, the focus is on what the learner learns rather than on what the lecturer teaches.
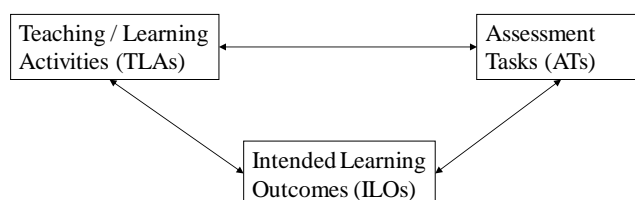

Figure 1. Constructive alignment framework

Table 1. Mapping between Intended Learning Outcomes (ILOs) and Programme Outcomes (POs)

No.	Intended Learning Outcome (ILO): After successfully completing this unit, students should be able to:	The Programme Outcomes (POs) which support the attainment of the ILO
ILO1	Construct a functioning prototype by integrating hardware and software components based on design concept	**PO 3 Development of Solutions** **PO 10 Individual and Team Work**;
ILO2	Perform and organize tests on the subsystems to assess strengths and shortcomings of the project and propose further improvements	**PO 4 Investigation,** **PO 10 Individual and Team Work**; **PO 12 Project Management and Finance**

ILO3	Demonstrate written and oral communication skills to present the project and the prototype	**PO4 Investigation** **PO9 Communication**; **PO10 Individual and Team Work**

Table 2. Mapping of Intended Learning Outcomes (ILOs), Assessment Tasks (ATs) and Teaching/Learning Activities (TLAs)

Teaching and Learning Activities (TLA)	Assessment Tasks (AT)	Intended Learning Outcome (ILO)		
		ILO 1	ILO 2	ILO3
Lectures – Classroom (3 hours per week) Material: case studies and research methodology	Presentation (35%): Individual (10%) and Group (25%)	Y	Y	Y
Teaching strategy: i.Group-based discussion ii.Collaborative learning	Working Demonstration: Group (10 %)	N	Y	Y
	Peer Assessment: Individual (5%)	Y	Y	Y
Lab sessions – Working Lab (3 hours per week) i)Use of simulation ii)Project-based learning	Project Report (50%): Individual (40%) and Group (10%)	Y	Y	Y

Note: Y = Yes and N = No.

In the new curriculum design, the assessment tasks (ATs) is developed based on topics or challenges provided by the Industry Advisory Panel members (IAPs) whereby in the previous design, the topics come from the lecturers or the convener of the course. Industry Advisory Panel (IAP) consists of industry experts who provide an industry perspective on the functions and operations of the academic departments. IAP members were generally engaged for the annual meeting and industrial lectures/talks. In the new curriculum design, we are also expecting the IAP member to actively participate in the capstone project.

At the beginning of the semester, groups of three or four students are formed based on the students' preference and are assigned to one teacher as an advisor. All groups will have a similar topic to solve. These groups will sit together during classes and take part in group-based discussions, group activities, and the group project. Collaborative learning and cooperative learning are encouraged within these groups to understand the modules which are delivered during class time. As the project based on industry requirement, we also invite some experts from the industries to give talks. The remainder of the class time is used to present problems and have groups develop, present, and discuss solutions. Active participation of the students is expected.

During the practical lab, students are guided to organize and perform their own work. In preparation for the lab sessions, they are required to complete preliminary works. At the end of the project, students are expected to come up with a working prototype, a presentation, and a report.

The working prototype will be assessed by experts from the industry and will contribute to 10% of the total marks. For the presentation, it will be assessed by fellow teachers in the department. There are two parts of the presentation, individual presentation (contributing to 10% of the marks) and group presentation (contributing to 25% of the marks). The report will be marked and assessed by the teacher of the course and the advisor. The report is divided into two; individual report (contributing to 40% of the marks) and group report (contributing to 10% of the marks).

2.3.   Assessment grading

In the capstone project course, rubrics are developed as feedback and grading tool for student's performance. Rubrics are a criterion-referenced assessment. Criterion-referenced assessment is the process of evaluating and grading of students 'performance against a set of pre-specified qualities or criteria, without reference to the achievement of others in the cohort or group (Frey *et al.,* 2012). For each of the criteria, standards are described for each level of achievement. When a grade is assigned, it is assigned on the basis of the standard the student has achieved on each of the criteria (Lok *et al.,* 2016).

In developing the criteria for the rubrics, a report prepared by Moira Cordiner is referred (http://www.teaching-learning.utas.edu.au/assessment/how-do-i-write-criteria-sheets). In her report, she mentioned two basic guidelines, which are 1) criteria must be related to the intended learning outcomes (ILOs) and 2) criteria are descriptors of what we are looking in student responses of the intended learning outcomes. For example, in ILO3 of the capstone project course, students are expected to demonstrate communication skills in presenting the prototype. As one of the grading criteria, this is related to technical communication. So we set technical communication as one of the criteria with four levels of a standard; poor explanation skill for the first level, satisfactory explanation skill with a couple of mistakes for the second level, good explanation skill with the minimum mistake for the third level and excellent explanation with no mistake for the fourth level. **Table 3** shows the example of rubrics used for assessing individual presentation. There are two types of criteria in rubrics; unit-specific and task-specific. We choose to use task-specific which will help students to understand what is required.

Table 4 shows the example rubrics used by the external examiner (industry advisors) for assessing the prototype or the working model.

Besides the above rubrics, we have rubrics for assessing group presentation and rubrics for asessing the report.

The criteria of each rubric are proposed by a group of lecturers together with industry advisors that involve in the capstone project before the semester starts and are approved in the Department meeting.

3.   RESULTS

Data were recorded from two cohorts of students who enrolled in the capstone project course. The first cohort, consists of 17 students, was conducted with previous curriculum design while the second cohort, consists of 19 students, was conducted with the new design. The topic for the first cohort was "Developing a Solar Tracker System" and the topic for the second cohort was "Developing a Low-Cost Scanner for A2, A1, and A0 Papers". **Figure 3** shows examples of low-cost scanner devices developed by the students.

Table 3. Rubric – Individual presentation

Presentation: Individual – ILO3 mapped to PO9

Criteria	Score
a) Use of presentation visuals	
b) Time management	
c) Delivery	
d) Technical communication	
e) Ability to justify the proposed solution	
Total	

Evaluation Guidelines:

Criteria	0.5 %	1.0 %	1.5 %	2.0 %
a.	Students' visuals do not add up the presentation.	Students occasionally use visuals that supported the presentation.	Students' visuals are related well to the presentation.	Students use excellent visuals to reinforce the presentation.
b.	Exceed the time allocation by > 10 minutes	Exceed the allocated time between 6 – 10 minutes	Exceed the allocated time between 2 – 5 minutes	Good time keeping (exceeded time < 2 minutes)
c.	Poor command of language and fluency. Students do not look at people during the presentation.	Satisfactory command of language and fluency. Student appear stiff and there is limited eye contact with the audience.	Students use a clear voice and has good command of language and fluency. Students appear to be nervous and establishes some eye contact with a few person.	Students use a clear voice and has excellent command of language and fluency. Students appear relaxed and confident, and establishes good eye contact with most of the audience.
d.	Poor explanation on technical work	Satisfactory explanation on technical work. Some mistakes are found in the explanation.	Good explanation on technical work. Minor mistakes are found in the explanation.	Good / excellent explanation on technical work. No mistakes are found in the explanation.
e.	Answer question with low confidence. Unable to comprehend and/or answer questions.	Answer question with some confidence. Able to answer questions but unable to elaborate on the point.	Answer question with confidence. Able to answer questions and provide some elaboration on the point.	Positive and answer question very confidently. Able to answer questions and elaborate on the point clearly.

Table 4. Rubric – Prototype or working model

Working Model – ILO3 mapped to PO3

Criteria	Score
a. Functionality	
b. Features	
Total	

Evaluation Guidelines:

Criteria	1.2 %	2.4 %	3.7 %	5.0 %
a.	Prototype is not functioning or there is no prototype.	Some features of the prototype are functioning.	Prototype is functioning with little errors.	Prototype is functioning well.
b.	Features of the prototype is not logical.	Features of the prototype is not logical.	Features of the prototype is logical.	Features of the prototype is very logical.

(a)   (b)

Figure 3. Low-cost scanner devices

From rubrics, we can determine the ILOs attainment. **Figure 4** shows the ILOs attainment of the first cohort, **Figure 5** shows the ILOs attainment of the second cohort and **Figure 6** combines the attainments from the first and second cohorts. **Figure 7** shows the POs attainment for the second cohort.

Figure 4 shows the mean of ILO 1 attainment is 45.4% with a median of 45.67% and standard deviation of 9.86. For ILO 2 attainment, we recorded a mean value of 58.15% with a median of 55.89% and standard deviation of 8.56. And for ILO 3 attainment, we recorded a mean value of 59.68% with a median of 58% and 8.86 standard deviation. Results show that all ILOs attainment of the first cohort is higher than 44% (target set by the university based on EAC requirement) but all are lower than 70%. From Figure 5, it shows the mean of ILO 1 attainment is 80.67% with a median of 81.43% and standard deviation of 6.42. For ILO 2 attainment, we recorded a mean value of 70.84% with a median of 70.13% and standard deviation of 3.54. For ILO 3 attainment, we recorded a mean value of 77.1% with a median

of 77.4% and 6.9 standard deviation. Results show that the ILOs attainment of the second cohort is higher than the ILOs attainment of the first cohort which can be seen in Figure 6; which shows that the ILOs attainments of the second cohort are higher than 70% indicating that we have achieved the learning outcomes for this course. High mark from industry experts was also recorded (8.5% out of 10%) indicating good appreciation from the industry.

With the current design, we can also measure the details of POs attainment. **Figure 7** shows the PO attainment of the second cohort.

Figure 7 shows that the second cohort achieves 75% PO 3 attainment (standard deviation of 0.15), 75% PO 4 attainment (standard deviation of 0.08), 71% PO 9 attainment (standard deviation of 0.1), 75% PO 10 attainment (standard deviation of 0.09) and 75% PO 12 attainment (standard deviation of 0.09). PO attainment of higher than 70% indicates that the course has contributed well to the program outcomes.
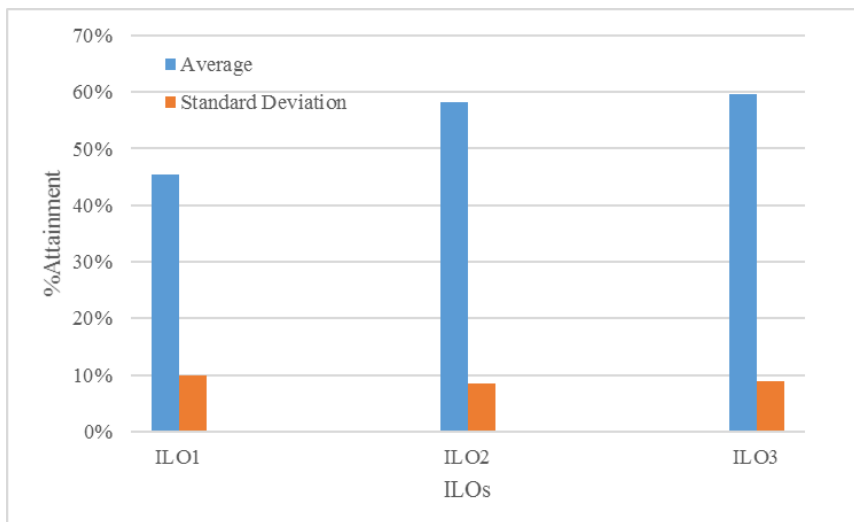

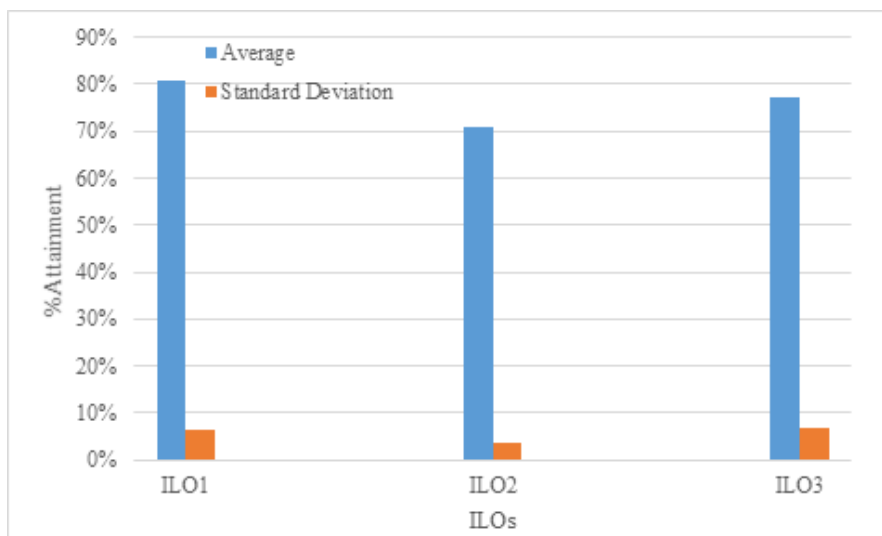**Figure 4.** ILOs attainment of the first cohort

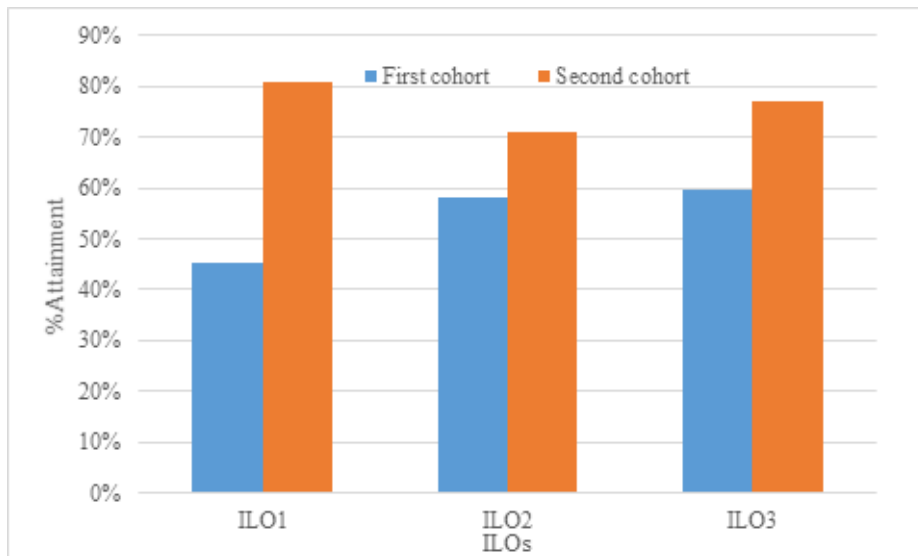**Figure 5.** ILOs attainment of the second cohort

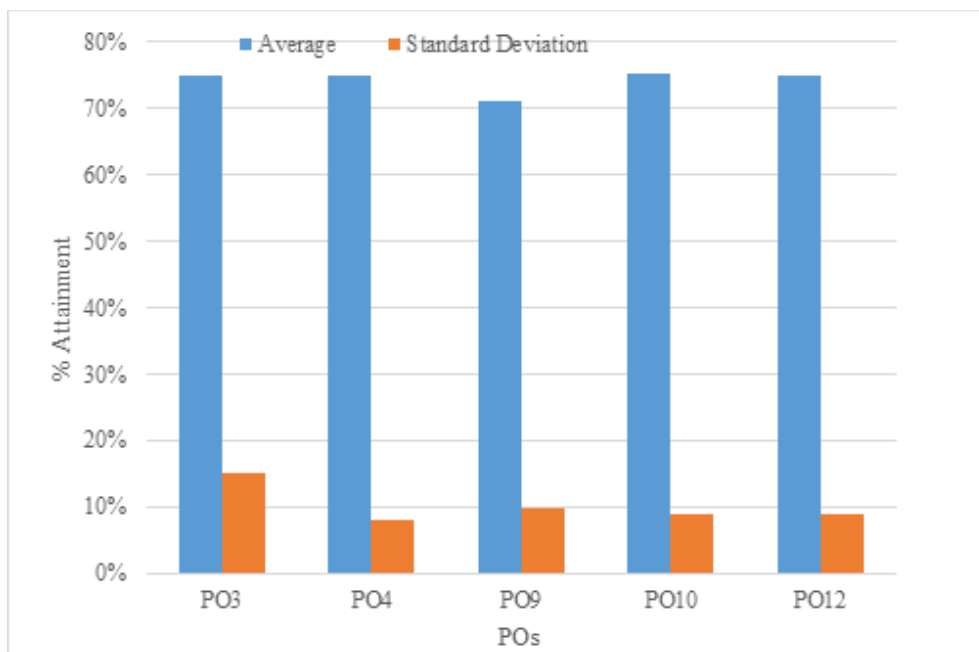**Figure 6.** ILOs attainment of first and second cohort

Figure 7. POs attainment of the second cohort

As we can see from the results, most of the students were getting good marks. This can be seen as 'grading on the top' problem. As stated by Bigss and Tang (Biggs and Tang, 2011), this is correct if we are based on norm-referenced assessment, where we see a course as a competition between student. In the norm-reference assessment, the actual quality of the student's performance is irrelevant. The norm-referenced assessment makes a judgment about people, not their performance. Criteria-referenced assessment, on the other hand, is expressed in terms of how well a given student's performance matches the criteria that have been set in advance. In the criteria-reference assessment, we assess the performance, not the people.

4. CONCLUSION

According to Ernst and Yong Report, most of the university models will be impractical over the next 10 to 15 years. To keep being practical, universities need to rethink on how they work. Project-based learning (PBL) is a student-driven, teacher-facilitated approach to learning. Researchers agree that project-based learning is one of the learning process, which can make the university to be practical, especially to satisfy industry need.

The capstone project is an example of project-based learning. Effective capstone projects are of high interest to employers of graduates. To have an effective capstone project, we need a proper curriculum design for a capstone project. In this report, we explain the steps taken, based on constructive alignment approach, to improve the performance of the capstone project course in the university.

At first, the curriculum should be aligned with external factors such as programme learning outcomes (which itself must be aligned with the requirements of the Engineering Accreditation Council, Malaysia (EAC), the Malaysian Qualification Framework (MQF), the Malaysia 7 Soft Skill and the Washington Accord Graduate Engineering Attributes) as shown in **Figure 1 and Table 1**. Next the map should also outline the internal relationships within the course – the intended learning outcomes (ILOs), teaching/learning activities (TLAs) and assessment tasks (TAs) – as shown in **Figure 1 and Table 2**.

Rubrics are used as feedback and grading tool for student's performance. Since rubrics are criterion-referenced assessment, the criteria are constructed based on the intended learning outcomes (ILOs) and act as descriptors of what we are looking in student responses of the intended learning outcomes as shown in Tables 3, 4, 5 and 6. Results show that an improvement of students' performance in comparison with previous students' cohort with all ILOs and POs attainment higher than 70%. The results are also in line with marks from industry experts (8.5% out of 10%) indicating good appreciation from the industry. This shows that the curriculum map that we developed for our capstone project has a good balance and perspective.

5. ACKNOWLEDGEMENT

6. AUTHORS' NOTE

The authors declare that there is no conflict of interest regarding the publication of this article. Authors confirmed that the paper was free of plagiarism.

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