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Utilisation of Learning Outcome Attainment Data to Drive Continual Quality Improvement of an Engineering Programme: A Case Study of Taylor's University*

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The current educational model adopted by all accredited engineering Schools (or faculties) in Malaysia follows an Outcome-Based Education (OBE) approach. To support this model, Schools adopt a variety of pedagogical techniques, ranging from traditional lecture-based learning to project-based learning. Learning outcome attainment data are essential in order to understand the impact of Outcome-Based Education and the associated pedagogies on the overall student learning experience. Using these data, a School may decide on how to improve its engineering programmes, as well as how to ensure that the programmes evolve in parallel to the developments within the industry and, more importantly, with the needs of the learners. This study discusses how the utilization of learning outcome attainment data and the tools used to mine them has affected the programme and the overall student learning experience. The study also details out how specific Continual Quality Improvement (CQI) action plans have affected learning outcome attainment, and their impact on pass, retention and graduation rates.

Keywords: outcome based education; learning outcomes; continual quality improvement

1. Introduction

In Outcome-Based Education (OBE), emphasis is put on the measurement of students' Module Learning Outcome (LO) attainment on a regular basis—e.g., at the end of each semester. LOs are crafted from the Programme Outcomes (POs) when the curriculum is developed. The corresponding professional body identifies the generic POs necessary within an engineering programme, which are then mapped to the qualification framework of the country. In this context, continual measurement of LOs and POs is required to gauge how students are progressing throughout their studies.

However, effective and transparent evaluation of POs is difficult because the majority of programmes do not share the POs or their assessment results with their stakeholders [1]. This has an impact on Continuous Quality Improvement (CQI), as engaging stakeholders means that external and internal feedback, based on the programme outcome attainment data, may be used to effectively enhance the programme. Furthermore, accreditation organizations and university management have an important role in enforcing effective PO assessments and transparent sharing of results that benefit students, staff, governing bodies and employers. An additional problem is that many institutions may have established LOs and a combination of programme-level and institution-level assessments, but they fail to inform changes in curriculum effectively [2], hindering the benefits of learning outcomes assessment.

While LOs provide one way to evaluate and measure the success of a cohort or individual students, there are two significant variables, related to student retention, that are essential in determining the success of a module or programme: graduation—or completion—rates and passing rates. Retention rates are important indicators and requirements for federal funding, as administrators need to be aware of how operational funds are being utilised in ensuring that students are being educated appropriately, thus leading to an acceptable graduation rate [3]. Graduation rates are often used as indicators of efficiency and accountability of higher education institutions, even though their definition and measurement vary across higher education institutions [4]. In the Malaysian context, the true-cohort method—where a cohort of students are tracked over a specific period of time—may be the most appropriate measurement of success because Malaysian students must graduate in a timeframe no longer than 1.5 times the minimum duration of study of a degree programme. Thus, graduation (or completion) rates in this research relate to tracking of a cohort of students as they progress through the minimum duration of their study. According to this, a graduation rate of 60% would imply that three out of five of students graduate within the stipulated years—in this research, that period is 4 years. Other authors propose similar definitions of this metric, such as the proportion of students who obtain their degree or the percentage of students who should graduate [5–7].

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Some authors attribute the decline in engineering enrolment rates to low retention rates [8–10]. As an example, annual graduation rates in America decreased by roughly 20% in the later part of the 20th century, even though a rise of 30% in engineering jobs was predicted. Low retention rates contribute to increased difficulty in attracting high School graduates into engineering, and economic, political and academic concerns back the need to oversee the time students take to graduate [11]. The relevance of graduation rates has led some authors to consider it as a rating indicator [12], and many countries monitor graduation rates and university rankings also use them as ranking indicators, because graduates who complete their degree on time are entering the workforce at the expected rate, contributing to national economic development. Furthermore, the longer a student takes to graduate, the lower the probability of the student actually graduating [13].

Universities make the effort to measure student outcome attainment data, but there are still opportunities to further use such data to improve their programmes. For example, to meaningfully engage external and internal stakeholders, and receive their feedback about student learning outcome data. Additionally, and despite the fact that many universities closely monitor retention rates, there is a dearth of research about if and how student learning outcome data, when used to enhance the programme, affects retention rates. Therefore, further analysis is needed to ascertain whether learning use of outcome data is related to student retention. Therefore, this research aims to explore the following research questions.

1. How can learning outcome data be used to add value to an engineering undergraduate degree programme?
2. Does CQI truly enhance the student learning experience (measured through higher retention rates)?

Based on the above, the research objectives of the present investigation are:

1. To describe the method and process of learning outcome data generation and its use for CQI in an engineering undergraduate programme, and
2. To explore the relation between learning outcomes and retention rates.

To align and baseline the definitions of the key variables, the research defines graduation rate as the percentage of students completing their degree on time; passing rate as the percentage of students that successfully pass a module within a programme—e.g., ‘‘the passing rate of Engineering Mathematics 1 is 75% would mean that 75% of the students enrolled in this module, in a particular semester, passed and successfully completed the module. The KPI within the School is a pass rate of 80%, which will be used henceforth as a ‘‘good’’ pass rate. Finally, retention rate relates to the percentage of students that are successfully retained in each semester, excluding those who have left or withdrawn the programme; as such, it is the opposite of attrition rate.

2. The OBE model at Taylor's University

In order to extract attainment data for later analysis and use them to develop CQI action plans at the programme and module levels, it is necessary to understand the OBE model implemented by the School. This in turn requires to explain the terms of student learning outcomes and objectives employed by the School.

Programme learning outcomes or POs are specific and measurable statements that are crafted by the engineering faculty and encapsulate the skills, knowledge and behaviour that students should acquire throughout the programme. Attainment of the POs is to be reached at the stage of graduation. POs are crafted from the Programme Educational Objectives (PEOs) of the programme. PEOs are statements that should ideally be embodied by the graduate student three to five years after graduation. PEOs are crafted from the Vision and Mission of the institution and can be mapped to POs. POs can be crafted based on numerous ideologies or pedagogies. For example, in the Malaysian context, it is required that all POs of an engineering programme of a Malaysian Higher Education institution must be mapped to the generic POs provided by the Engineering Accreditation Council of Malaysia. The generic POs are listed below [14]:

1. **Engineering Knowledge**: Apply knowledge of mathematics, science, engineering fundamentals and an engineering specialization to the solution of complex engineering problems;
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;
3. **Design/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;
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;
5. **Modern Tool Usage**: Create, select and apply appropriate techniques, resources, and modern engineering and IT tools, including prediction and modelling, to complex engineering activities, with an understanding of the limitations;
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;
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;
8. **Ethics**: Apply ethical principles and commit to professional ethics and responsibilities and norms of engineering practice;
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;
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;
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.
12. **Project Management and Finance**: Demonstrate knowledge and under-standing 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.

2.1 Description of the model

In order to train School graduates who embody the university's core purpose and show ability or the potential to meet its mission, the School crafts a set of PEOs. These statements embody what a graduate of the School should attain 3–5 years after graduation. In order to ensure that graduates meet these PEOs, data are mined from alumni and their employers, the Schools industrial advisory panel and the School's management. Data are then used to enhance or revise the PEOs, in the spirit of CQI, once every 3 years. This process is represented in the outer loop in Fig. 1.

The School also makes an effort to obtain data (through direct and indirect measurements) for each of its students PO attainments—middle loop in Fig. 1. Once again, the POs are a set of 12 statements that each student must attain at the point of graduation. Direct measurements are primarily obtained at the module level, through learning assessments. Learning outcome attainment data are obtained by feeding raw learning assessment scores through the School's ICT tool.

The inner-most loop represents the collection of learning outcome data at the module (course) level. Here, raw assessment scores are fed into the ICT tool and the relevant learning outcome attainment data is produced. Module coordinators then use these data to develop a specific and measurable CQI action plan, meant to enhance future learning outcome scores by enhancing the overall student learning experience. To further describe the process highlighted in the preceding section, the next subsections present and discuss a detailed step-by-step guide describing each loop and its implementation [15].

2.1.1 Learning outcomes

The LO loop focuses on single modules. Upon registration of the relevant assessment grades in the ICT tool, LO attainment scores for the cohort are available for the module lecturer or coordinator, and the latter proceeds to fill in a formal document which details the CQI action plan based on the LO and PO attainment scores of the cohort. The CQI action plan is then discussed with the School's management for initial input. The next step entails the discussion of the action plan between the module coordinator and academic staff within the programme for further input; this is called the CQI programme meeting, where observations can also be made at the PO level to check for existence of any tendency at the PO level. After the meeting, the staff proceeds to complete and update the action plan, which is endorsed and approved by the School's management and is actionable in the upcoming semester. At the end of the future semester, the module coordinator will have to elaborate on the success or failure of the action plan before recommending another one.

2.1.2 Programme outcomes

The School's management tracks the PO attainment of the cohort and provides an overall CQI report on a semester basis. At the end of the year, management then provides a CQI action plan for the programme at an annual Programme Review Meeting. The action plan is discussed within the School's

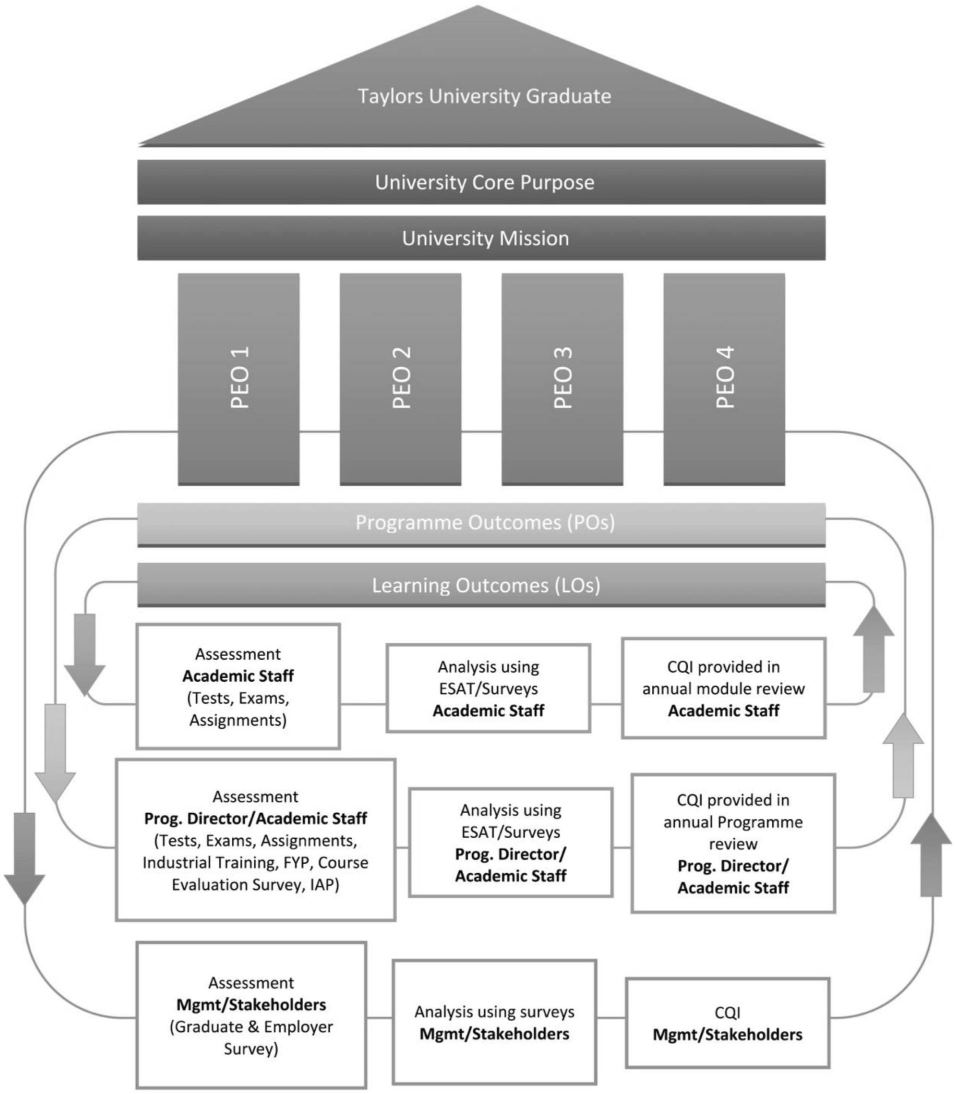

Fig. 1. School's OBE and CQI framework (a.k.a. constructive alignment).

management committee for initial input and is then discussed with the programme's academic staff prior to being finalised. Certain action plans would then require endorsement and input from internal (staff, students, senate) and external (industrial advisory panel, external examiners, parents, etc.) stakeholders.

2.1.3 Programme educational objectives

The final PEO loop includes the participation of different employers who will eventually hire the graduates. A detailed PEO survey is crafted to address the attainment of the PEOs. Attainment is based on a set of specific and measurable PEO KPIs. The fulfilment of these KPIs (the number of which depends on the administering institution) means a fulfilment of the PEOs. Once again, based on the feedback from the surveys, input is collected from both internal and external stakeholders prior to making any changes, which normally occurs three years after the student has graduated.

The processes described above highlight how the School utilises learning outcomes data to improve the overall programme's performance—specifically, graduation and passing rates, in the spirit of CQI. The CQI action plans described above are a result of direct measurements, i.e. through student learning outcome data.

2.2 Data collection and mapping

In addition to direct measurements, the School also collects data through indirect means, including a variety of surveys and the students' own self-assessment of their PO attainment, done through a creative resume that is an assessment component of a specific module in the programmes within the School. The creative resume requires students to highlight their achievements, strengths and areas of development and improvement. It also includes the student's description of their professional vision. Students also receive their own PO attainment data (elaborated by the School's ICT tool), allowing comparison with their own self-assessed PO scores, and thus enhancing their awareness about their learning shortcomings or gaps.

The ICT tool, implemented as a spreadsheet, calculates learning outcome attainment data—or scores—at the programme and module levels. LOs within a curriculum are mapped to the relevant POs of an undergraduate Engineering Degree (PO-LO mapping), while assessments within a module are mapped to the LOs (LO-assessment mapping), effectively linking assessments and POs. Student grades in the assessments are then used to calculate learning outcome scores.

For the sake of simplicity, a simple example is used to describe how the tool calculates learning outcomes as follows:

- Let us suppose that module A has 2 LOs (LO1, LO2), and LO1 may be mapped to PO1 (and LO2 to PO2).
- Let us also suppose that module A only has 1 assessment component—e.g., an exam with 2 questions.
  - Question 1 has a maximum score of 70 and maps to LO1.
  - Question 2 has a maximum score of 30 and maps to LO2.
- Then, a student scoring 50 out 70 for question 1 will have an LO1 attainment score of 50/70, or 71%. Because LO1 is mapped to PO1, the students' PO1 score would also be 71%.
- A similar method would then be used to calculate LO2 and PO2 scores.

The scenario above oversimplifies the calculation needed to produce LO and PO scores. Note that there may be many different modules, each with a different number of LOs, within a programme, and also that they map to many POs and that each module includes a variety of assignments and assessments, each one assessing a specific number of LOs. All the information from the LOs and POs is collected on a spreadsheet, described in [16, 17], to calculate the learning outcome scores. The calculation process is as follows:

- At the module level, each assessment component is mapped to at least one LO, and each LO is mapped to at least one PO. For simplicity, all mapped POs are given similar weights.
- Then, each LO and PO attainment is calculated following Eqs. (1) to (4).

$$\text{LO score} = \sum \text{LO component score mapped to assessment components} \qquad (1)$$

$$\text{LO Attainment} = \frac{\text{LO score}}{\text{Maximum expected LO score}} \qquad (2)$$

$$\text{PO score} = \sum \frac{\text{LO score mapped to the PO}}{\text{No. of POs mapped to that LO}} \qquad (3)$$

$$\text{PO Attainment} = \frac{\text{PO score}}{\text{Maximum expected PO score}} \qquad (4)$$

- For each student, a particular LO and PO is attained if his or her LO and/or PO score is equal to, or greater than, the KPI set by the School.
- Consequently, the module LO and PO attainments are based on the percentage of students achieving the KPI. For example, if the KPI is set to 60%, we consider the LO/PO attained if 60% of the students in a cohort achieved the 60% of the LO/PO score. The reason for using 60% is to ensure that a student has achieved more than half of the learning outcome score. Anything less would be close to half, and anything more would be unrealistic. Furthermore, a learning outcome score of 60% is almost equivalent to a passing score of 50%, although there is no generic rule supporting this.

Students are also provided with their PO attainment data as a radar or spider-web chart. Fig. 2 illustrates an example of the chart for a cohort –note it is also possible to generate individual results. The School's ICT tool generates the PO scores, and the outer radar line represents the cohorts PO scores (in Fig. 2, there are 12 POs in total) while the inner radar line represents the School's KPI, which lies at 60%.

As explained above, learning outcome scores data are then used to develop specific action plans related to modules and the programme. At the end of every semester, lecturers must design specific CQI actions for individual modules using the LO scores. The plan is discussed and endorsed by the faculty, and implementation occurs in the following semester. This process happens twice every year—for a programme including both semesters. The School management then has to develop CQI annual action plans for the programme based on PO scores.

2.3 *Data collection*

The schematic depicted in Fig. 3 shows the process used for data collection about the key areas or variables.

The process begins with the assessment of whether a student passes a module. If a student passes the module and "progresses", he or she would contribute to the modules' passing rate and the data is captured by the academic services department. Consequently, and since the student has passed, the lecturer would then insert the relevant assessment scores into the ICT tool to calculate LO

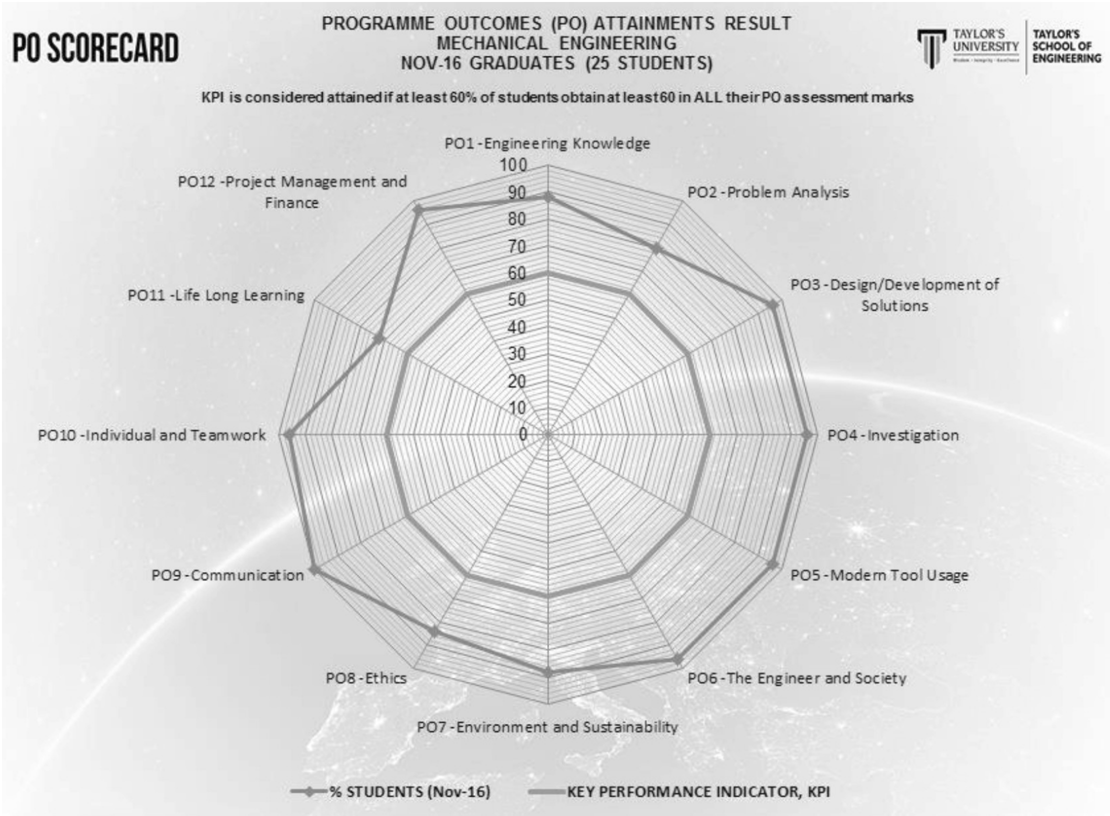

Fig. 2. Student's PO scores generated using the ICT tool (for a cohort of students).

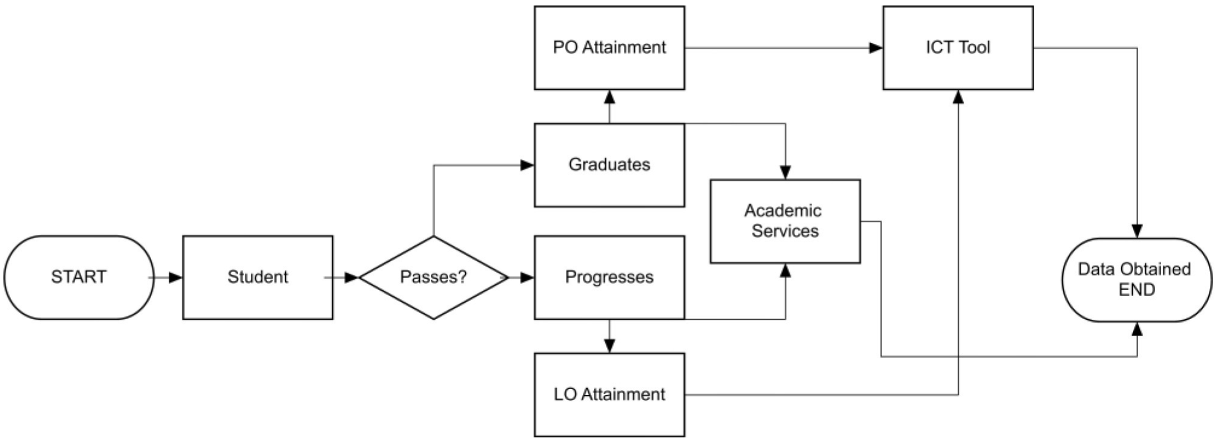

Fig. 3. Data collection Process.

attainment, which is stored in the tool's master database.

Collection of passing rates and LO attainment would require extraction of the relevant data from both academic services and the ICT tool, respectively. Similarly, if a student passes and is in his or her final semester, a successful passing of all modules during that semester would lead to graduation, and therefore contribute to graduation rate—captured by academic services. Students who graduate are then shown their overall PO attainment score—computed by the ICT tool. Same as before, obtaining the graduation rates and PO attainment requires extracting the relevant data from academic services and the ICT tool, respectively.

3. Assessing the impact of PO and LO data on CQI

This study includes learning outcome data from the entire School during 2015 and 2016. Following Fig. 1, data were used to develop CQI actions at both the

Table 1. Graduation rates

	Number of Students (%)					
Programme Name	**March 2015 Semester**	**August 2015 Semester**	**Year 2015 Average**	**March 2016 Semester**	**August 2016 Semester**	**Year 2016 Average**
Chemical Engineering	83	62	**73**	87	72	**80**
Electrical & Electronic Engineering	67	90	**79**	82	100	**91**
Mechanical Engineering	87	52	**70**	73	70	**72**

Table 2. Passing rates

	Number of Students (%)					
Programme Name	**March 2015 Semester**	**August 2015 Semester**	**Year 2015 Average**	**March 2016 Semester**	**August 2016 Semester**	**Year 2016 Average**
Chemical Engineering	92	84	**88**	92	92	**92**
Electrical & Electronic Engineering	91	74	**83**	67	89	**78**
Mechanical Engineering	88	77	**83**	80	76	**78**

Table 3. All LO attainments (ME, EE & CE)

	Number of Modules (%)					
Programme Name	**March 2015 Semester**	**August 2015 Semester**	**Year 2015 Average**	**March 2016 Semester**	**August 2016 Semester**	**Year 2016 Average**
Chemical Engineering	71	32	**52**	53	70	**62**
Electrical & Electronic Engineering	54	29	**42**	55	53	**54**
Mechanical Engineering	55	30	**43**	54	58	**56**

programme and module level, covering four semesters of a 4-year engineering programme. It should be noted that not all modules could be included because some of them may not have been offered over this two-year period. An average of over 30 modules are offered per programme in one semester, most of them being taught only on one of the two semesters. Furthermore the data used in this study includes three engineering programmes: Chemical Engineering (CE), Electrical & Electronic Engineering (EE) and Mechanical Engineering (ME).

3.1 Results

Table 1 provides information about the individual programmes students' graduation rates. From Table 1, the average graduation rate increases from year 2015 to year 2016 in all three courses—even though the increase in the ME is minimal.

Table 2 presents the number of modules, in percentage, with a passing rate of 80% or more. As seen in Table 2, there is an increase in the average number of modules with passing rates over 80% between 2015 and 2016 for the CE programme, and a slight decrease in the EE and ME programmes.

Additionally, the data reported by the School's ICT system over the same two-year period (Table 3) give information about the percentage of students that attained all LOs for modules offered over the 4 semesters. As shown in Table 3, the percentage of students attaining all LOs in the relevant modules increases from August 2015 onwards, with the exception of the EE programme. Furthermore, the number of students attaining all LOs decreases across all programmes between March 2015 and August 2015.

3.2 Discussion

While the tables in section 3.1 and the graphs shown in this section present the same data, the graphs and explanations here provide further insight about trends. Figs. 4–6 illustrate the data provided in Table 1, focusing on yearly average data. Fig. 4 illustrates the graduation rates, and shows that the CE, EE and ME programmes experience an increase in graduation rates (73% to 80%, 79% to 91%, and 70% to 72%, respectively).

Figure 5 depicts pass rates and shows an increase from 88% to 92% in the CE programme, and a decrease in the EE and ME programmes—a drop from 83% to 78% over the two-year period. A possible explanation is that the reason for this drop in pass rates could lie on CQI actions aiming to increase the depth and breadth of relevant modules. In some cases, certain modules within the School obtain exceptionally high pass rates and have a high number of students scoring A's. Further probing into such modules identify LOs that are not reflective of the depth and breadth required of a

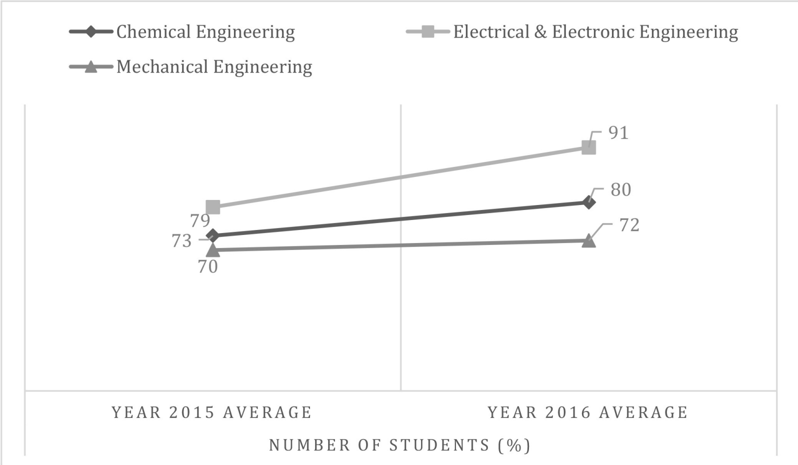

Fig. 4. Graduation rates.

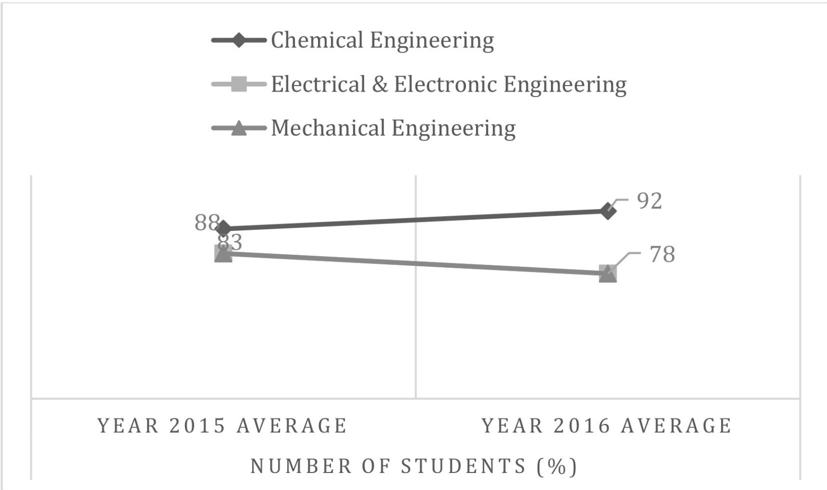

Fig. 5. Passing rates.

module within a certain year of the undergraduate degree. For example, a third-year module would require students to be able to explain and apply engineering theory to analyse an engineering system in order for them to assess the systems' success in addressing a particular engineering challenge. Thus, the LOs would need to change, to appropriately reflect the depth and breadth (from a Bloom's taxonomy level perspective) required in such modules. As a result, the difficulty or complexity of the module increases, causing pass rates to drop.

Figure 6 shows the number of modules where students have achieved the School's KPI for all LOs over the two-year period. From Fig. 6, the CE, EE and ME programmes experienced an increase of over 10%—from 52% to 62%, 42% to 54% and 43% to 56%, respectively. As noted earlier (Table 3), the number of students attaining all LOs decreases across all programmes between March 2015 and August 2015. The same cause as in the case of pass rates might also apply here.

An alternative explanation, though, might be a change in LO-assessment mapping: the mapping may have been changed due to internal shifts (CQI) or through external input (by external examiners or accrediting bodies). Changes in mapping may affect LO attainment because, if an assessment component were to be mapped previously to two LOs within a module, the students' grades for that assessment would contribute to both LOs, but if one LO was dropped after re-mapping, the contribution of this assessment would correspond to one LO, thus reducing the LO attainment for the second LO.

As the analysis only includes two data points per programme, a further statistical analysis might prove insufficient to generalize the results from this research. Overall, the results suggest that the use of PO and LO scores for the development of CQI action plans aiming to enhance specific areas within the programme do add value. Moreover, CQI action plans are developed to further enhance learning outcome attainment as the programme

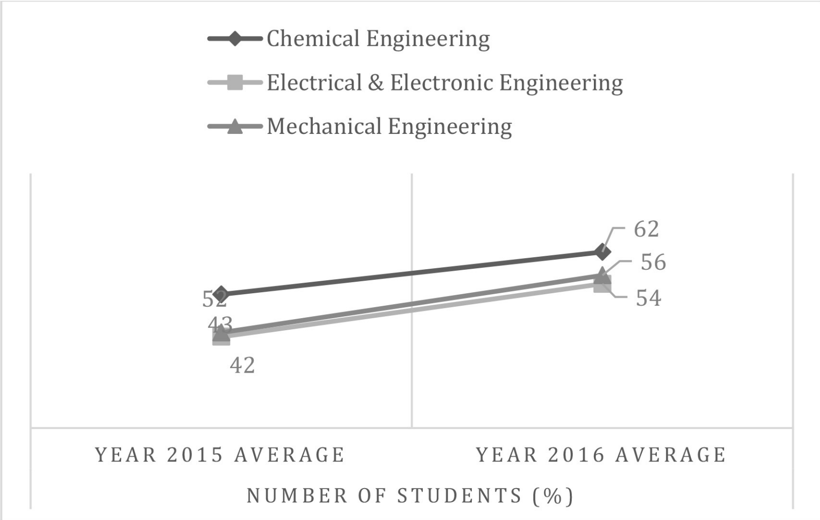

Fig. 6. All LO attainment per year.

matures. Examples of some of the CQI action plans that were implemented include the following:

- The need to enhance faculty-teaching skills.
- Revision of the learning outcomes to appropriately map to the depth and breadth of a module.
- Revision of the mapping of module learning outcomes to the relevant assessments, in order to ensure accurate and explicit attainment.
- Revision of the mapping of modules' LOs to POs to ensure accurate and explicit attainment.
- Change of the delivery methods or development of new strategies to further enhance learning. For example, developing a formative assessment plan to gauge learning more consistently; this action allows lecturers to adjust to the learning style of a specific cohort of students, making learning more personalized while allowing the development of different pedagogic strategies—e.g., case-based learning or project-based learning. Use of technology or blended learning to enhance learning.

The impact of learning outcomes scores on retention requires a more in-depth study to provide a valuable analysis and conclusion. Retention rates at the School over the two-year period were, as of November 2016, 94.9% (2015) and 93.2% (2016, a decrease of 1.7%). This drop is equivalent to 11 students, considering the total number of students at that moment. While this is definitely concerning, and it might initially indicate that CQI actions were ineffective, a closer look at the general context might provide another explanation, given the existence of a stack of students accumulating over the period of 3–4 years and who were close to being terminated from the programmes due to academic reasons.

4. Conclusion

The present study aimed to exam the effect of learning outcome data on the improvement of an engineering undergraduate programme. In order to make meaningful decisions that positively impact the quality of an academic programme, it is necessary to assess LO and PO data, a scenario where the application of academic analytics could be helpful. This study discusses how learning outcome attainment data informs academic management in making decisions to improve academic programmes, in the spirit of CQI. The decisions made must then be further evaluated by examining its impact on student learning—and more specifically, on student retention. Once the impact is understood, further decisions can be made to improve the programme in a more meaningful manner. The research also describes the methodology and process to generate learning outcome data using an ICT tool developed for this purpose. The results show an overall increase in graduation rates and in the number of modules with students achieving all LOs within a module. The results seem to confirm that using learning outcome data for CQI processes can improve student learning, measured as graduation rates and pass rates. Nonetheless, further investigation is required about how CQI affects pass rates; more particularly, CQI aiming to increase the depth and breadth of a module, as it might negatively affect pass rates. This research also calls for a more holistic view on CQI, where increases in depth and breadth need to be complemented with a more comprehensive student support system. That way, students would receive adequate support and be better prepared for assessments that are more complex and belong in a higher level in Bloom's taxonomy.

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