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A comparative study of Bachelor of Electrical Engineering programmes in terms of students' performance

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ABSTRACT: This study was aimed at measuring and comparing the effectiveness of two curricular structures in the Faculty of Electrical Engineering at the Technical University of Malaysia of Malacca (Universiti Teknikal Malaysia Melaka - UTeM). The comparison involved two programmes for a Bachelor of Engineering degree. One of them was a conventional academic programme and was offered to potential candidates as conventional electrical engineering (EE); and the other one was a broad programme referred to as BEKG. Data generated from students' performances for the conventional EE and the BEKG programme were compared to assess how the EE curriculum is delivered at the University. The study targeted five categories of subjects, such as mathematics and basic science, laboratory, electrical, elective subjects and the final year project. The results indicate that the students' mean performance in BEKG was better than that in the conventional EE across most of the categories. The outcome of this study could be useful to researchers and policymakers to improve EE curricula and teaching approaches.

Keywords: Teaching performance, electrical engineering subject, student performance

INTRODUCTION

Preparing electrical engineering (EE) graduates to fulfil the Engineering Accreditation Council (EAC), Malaysia, and the Malaysian Qualifications Agency (MQA) requirements has brought a challenge to the academic community in Malaysia. Assessment plays a significant role in the quality assurance and continuous improvement of the EE programme [1]. Ideally, the curriculum of the Faculty of Electrical Engineering (FKE) at the Technical University of Malaysia of Malacca (Universiti Teknikal Malaysia Melaka - UTeM), should be based on 60% practical and 40% theoretical content [2]. Since 2010, the teaching and learning activities in the Faculty have followed an outcome-based educational approach within a conventional EE programme. However, starting from the academic session 2014/2015 [3], the Faculty has substituted the conventional EE curriculum with a new broad programme for the Bachelor of EE course with the specialisation starting in the second semester of the third year, referred to in this, and other publications as BEKG [4]. Recently, several authors discussed different methods of programme objectives (PO) attainment in various case studies [5-11]. For example, Faiz and Almutairi focused on an engineering technology course [6], while Aziah et al researched students' performance in an electrical engineering programme and analysed the students' grade in each course [11]. However, no study has looked into the quality of the EE programme in the FKE, UTeM in terms of evaluation and assessment of students' performance. Thus, this study aimed to provide a comparative analysis of the conventional EE and BEKG programmes that differ in the curriculum structure.

To simplify data gathering, the data extraction in this study used students' performance records from these two programmes based on two different cohorts. The minimal criteria for both cohorts that registered for these programmes are presumed to be met. This study was undertaken at one specific faculty only, and the respondents were students from different cohort intakes from two academic EE programmes in the Faculty. Therefore, the study outcomes could not be generalised in the context of a Bachelor of EE programmes at other universities. Hence, further studies comparing different cohort intakes could be beneficial and enrich the outcomes of this study. This study aimed specifically to evaluate students' performance based on different curriculum structures in the FKE, UTeM. It continues and expends the preliminary work by Aziah et al carried out earlier, in relation to interdisciplinary and elective topics [12]. In this article, the authors discuss the data set, which covers the database construction and extraction. From these data, statistical analysis was conducted to identify whether the mean performance of BEKG students was better than that of the conventional EE ones. The results are based on the grading system used in the Penerbit Universiti, *Academic Handbook* [3] to enable trend identification in the tabulated data. The findings of the proposed approach provided a step to improving the quality of the EE programme in one faculty. However, they also contribute to the body of literature in the EE curriculum structure.

In the conventional EE programme, students are divided into three major courses at the beginning of the programme, which is Industrial Power (BEKP), Control, Instrumentation and Automation (BEKC), and Power Electronics and Drive (BEKE), as stated in two Penerbit Universiti *Handbooks* [2][3]. Table 1 shows the summary of curriculum content for conventional EE taken by electrical engineering students at UTeM based on the total credit hours divided between different subjects. Based on Table 1, the conventional EE programme focuses more on the electrical engineering subject and general knowledge that contribute 60% and 17%, respectively, from the content of the programme. This is due to the principle of the FKE, UTeM, which is to provide students with a solid foundation of EE knowledge. The curriculum structure has been revised by FKE stakeholders, such as the Faculty's external examiner, visiting professor, adjunct professor and an industrial advisory panel.

Table 1: Summary of the electrical engineering curriculum content based on 136 total credit hours.

Subjects	Conventional EE (%)	BEKG (%)
General Knowledge	17	13
Mathematics	11	10
Laboratory	8	5
Practical	4	4
Electrical Engineering	60	50
Multidisciplinary subject	N/A	9
Elective subject	N/A	9

In the BEKG programme, students follow the Faculty's curriculum structure until their fifth semester of study, with the distribution of credits points as illustrated in Table 1. Then, they select other subjects according to their interest in semesters six, seven and eight, when the Faculty offers another 9% total credit hours of the curriculum structure for an elective subject. This elective subject is selected based on three major courses offered previously in the FKE, UTeM, which are Industrial Power (BEKP); Control, Instrumentation and Automation (BEKC), and Power Electronics and Drive (BEKE), as stated in the academic handbook mentioned earlier [2].

An additional 9% of the content of multidisciplinary subjects has been added to the BEKG programme to incorporate the development of lifelong learning attitude, and an ability to consistently adapt to learning technology and entrepreneurial endeavours. Generally, the BEKG programme has been conducted with 80% of contact hours highlighting the theoretical content, and 20% of hours involving practical or laboratory experiments, computer-aided learning and problem-based learning (PBL) [4].

BUILDING THE DATA SET

This study aimed to evaluate the performance of students after the implementation of a new curriculum structure in relation to the old structure. Hence, two groups were identified, known as conventional EE and BEKG. The purpose was to demonstrate if the BEKG programme outperforms the traditional EE curriculum.

Let μ_1 and μ_2 be considered as the sample mean of students' performance for the conventional EE and BEKG programme, respectively. Thus, the hypotheses of the study refer to significant changes in the mean performance of BEKG students in relation to the mean performance of conventional EE students, and are stated as:

$$H_0: \mu_1 - \mu_2 \leq 0, \quad H_1: \mu_1 - \mu_2 > 0 \tag{1}$$

For comparison, two data sets were analysed, including students' performance from the 2013 cohort in the conventional EE and the students' performance from the 2014 cohort in BEKG. It should be noted that the student intake for the 2013 cohort was grouped into three primary courses: BEKP - 76 students, BEKC - 76 students and BEKE - 61 students. There were 150 students in the 2014 cohort. Moreover, both programmes applied the same teaching work procedure based on the UTeM quality management system [13].

Database Generation

To observe students' performance in the curriculum structure, subjects were divided into five categories considering all elements of subjects involved in the EE curriculum. The subject categories were as follows:

First, *mathematics and basic science subjects* play a fundamental role in supporting EE education mainly because engineering problems are based on mathematical modelling, and basic science is a vital frontier of modern technology [14]. Ideally, students with a strong knowledge of these fundamental subjects should perform well in engineering subjects. In this category, computer programming is defined as a basic science subject, while the rest of the subjects are defined as mathematics subjects.

The next category is for *electrical subjects*. The new BEKG curriculum introduced several electrical subjects and upgraded some from the conventional EE programme. In this article, the authors only consider four EE subjects to determine the effectiveness of shifting from the conventional EE to the BEKG programme. The performance of students in the electrical engineering subjects in the conventional EE programme including Instrumentation and Measurement (Instrument), Electromagnetic Theory (EMT), Introduction to Power Engineering, and Electrical Circuit 1, is compared to the BEKG programme subjects, such as Instrument, EMT, Power System and High Voltage, and Circuit Analysis.

The third category is for the *laboratory subject*. Students of the conventional EE programme must attend eight laboratory subjects in their first and second years of studies. Whereas, in the new structure of laboratory subjects for BEKG, two or three laboratory subjects from the conventional EE are merged into one laboratory subject. For instance, Electrical Engineering Laboratory 1 in BEKG consists of elements from Basic EE Laboratory, Analogue and Digital Laboratory and Electrical Technology Laboratory from the conventional EE laboratory subjects. By rebranding these laboratory subjects in the new curriculum structure, the students have the experience of three major laboratory courses in conventional EE.

The Integrated Design Project (IDP) subject is introduced to integrate the student's knowledge with other engineering courses and evaluate accordingly not limiting to EE. Also, a few disciplines have undergone improvements in teaching implementation in order to increase student understanding. For example, the teaching of the Modern Electrical Drive subject is conducted by combining lecture sessions with laboratory work. In doing so, students' performance is improved without compromising the practical subjects.

In the BEKG programme, the *elective subject* is introduced separately in semesters six, seven and eight. However, these subjects were originally bound by three programmes in the conventional EE programme. Therefore, a few electrical subjects in the conventional EE programme needed to be compared with those selected subjects in the new elective subjects in BEKG [3]. The proposal for the implementation of these elective subjects in the BEKG programme was approved by the UTeM Senate [4].

The final category, the *final year project (FYP)* is the most significant component in the curriculum structure for electrical engineering students. With six credit hours assigned to FYP, it requires 163 PBL contact hours for student learning time (SLT). Generally, one credit hour is approximately equivalent to 40 SLT. Thus, to assess the implementation of the curriculum for the Bachelor in EE, the FYP performance summarises the whole assessment of the programme.

Database Extraction

Data extraction is crucial in creating distinct data sets on students' performance based on the subjects undertaken and the categories for each programme. In this section, students' performance is identified to make a general comparison. Let *P* denote the list of programmes. Respectively, the category and subject, are denoted by *i* and *j*, selected from five considered categories, where N_i is the total number of subjects in each category *i*. By defining *g* as a set of 11 levels of the grading system presented in the FKE's *Handbook* [3], the respective number of students with grade *g* and the total number of students for the respective subject *j* in the category *i* of programme *P* is denoted as $s_{i,j}^{P,g}$, and their $M_{i,j}^{P}$ are obtained. The implementation steps to compute the percentage ratio between the selected data are depicted in Figure 1. The grade performance levels indicate different categories of achievement in students' performance, where an excellent grade and a minimum passing grade for a subject is grade A and D, respectively.

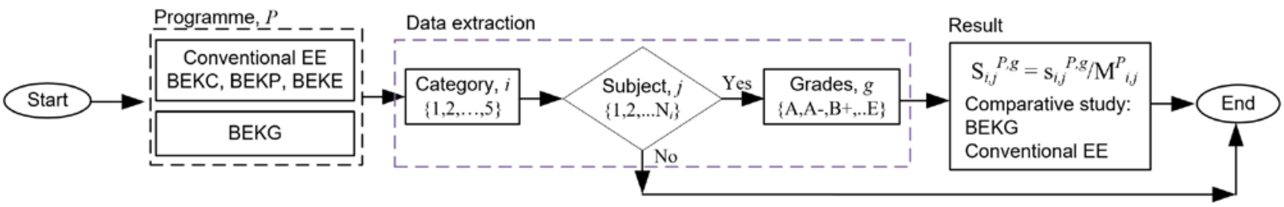

Figure 1: Implementation steps for the comparative study.

RESULTS AND DISCUSSION

This study's aim was to investigate and compare the conventional EE and BEKG programmes in five categories of subjects. Table 2 shows the performance of FKE students in mathematics and basic science subjects.

Table 2: Mathematics and basic science performance by the 2013 conventional EE cohort and the 2014 BEKG cohort.

Subject	Engineering Mathematics		Numerical Methods		Differential Equations		Algebra and Calculus		Computer Programming	
Programme	EE	BEKG	EE	BEKG	EE	BEKG	EE	BEKG	EE	BEKG
Excellent	43.28	26.98	18.29	46.71	29.39	33.33	47.71	30.99	5.31	15.74
Honours	28.73	24.01	23.17	25.26	16.67	24.89	25.23	28.46	12.08	17.13
Pass	24.25	39.83	48.37	24.68	39.04	34.37	25.69	35.87	71.50	47.69
Conditional pass	3.36	8.05	8.13	3.00	13.16	6.07	1.38	3.90	11.11	15.28
Fail	0.37	1.13	2.03	0.35	1.75	1.33	0.00	0.78	0.00	4.17

This table illustrates that BEKG students achieved higher grades in Numerical Methods, Differential Equations and Computer Programming than those in the conventional EE programme. Moreover, the BEKG students outperformed the conventional EE programme students with three times more excellent grades in Numerical Methods.

Table 3 shows the performance of FKE students in the selected EE subjects. Firstly, in the Instrument subject, the BEKG students' performance is better than the conventional EE students both at the excellent and honours level. A comparison of students' performance between the Introduction to Power Engineering conventional subject and the Power System and High Voltage new subject found that the BEKG students outperformed the conventional EE programme students. Fifty-five percent of the BEKG students scored honours and excellent grades, which is a far better achievement compared to the conventional EE students. The BEKG students also scored far more excellent grades in the EMT subject, making a huge improvement when compared to the conventional EE programme students. The improvement indicates that the BEKG students have a better mathematics preparation than the conventional EE programme students.

Table 3: Selected electrical engineering subjects for the 2013 conventional EE cohort and the 2014 BEKG cohort.

Subject	Instrumentation and Control		Electromagnetic Theory		Power System and High Voltage		Circuits Analysis	
Programme	EE	BEKG	EE	BEKG	EE	BEKG	EE	BEKG
Excellent	13.04	18.78	6.67	41.14	11.63	25.27	13.59	13.29
Honours	21.74	23.76	11.37	30.86	19.77	30.22	26.21	11.19
Pass	51.21	41.44	49.41	21.14	41.09	32.97	50.49	41.96
Conditional pass	12.08	12.71	25.49	5.14	20.16	9.34	7.28	24.48
Fail	1.93	3.31	7.06	1.71	7.36	2.20	2.43	9.09

Tables 4 and 5 show the performance of FKE students in the laboratory subjects for the conventional EE and the BEKG programme, respectively. Despite the rebranding of laboratory subjects for BEKG, the overall performance in the laboratory subject is similar to the conventional EE programme. However, a more focused subject comparison indicates a positive direction for the BEKG new curriculum structure, particularly for some laboratory subjects. By revising the content and its quality and delivery during each laboratory session, students' performance in all laboratory subjects can be improved further.

Table 4: Laboratory subjects and the corresponding grades in the conventional EE programme.

Subjects	Excellent	Honours	Pass	Conditional pass	Fail
Basic Electrical and Electronic Laboratory	57.58	39.39	3.03	0.00	0.00
Analogue and Digital Laboratory	40.70	37.19	21.61	0.50	0.00
Electrical Technology Laboratory	33.47	47.81	18.73	0.00	0.00
Electrical Engineering Laboratory 1	28.05	55.28	16.26	0.41	0.00
Electrical Engineering Laboratory 2	79.53	18.11	2.36	0.00	0.00
Engineering Practice I	79.71	20.29	0.00	0.00	0.00
Industrial Power Engineering Laboratory 1	70.59	24.37	5.04	0.00	0.00
Industrial Power Engineering Laboratory 2	96.67	3.33	0.00	0.00	0.00
Control Instrument Automation Engineering Laboratory 1	89.04	9.59	1.37	0.00	0.00
Control Instrument Automation Engineering Laboratory 2	12.16	33.78	51.35	2.70	0.00
Power Electronics and Drives Laboratory 1	25.00	28.13	46.88	0.00	0.00

Table 5: Laboratory subjects and the corresponding grades in the BEKG programme.

Subjects	Excellent	Honours	Pass	Conditional pass	Fail
Engineering Practice I	63.70	22.96	12.59	0.00	0.74
Engineering Practice II	71.85	22.22	5.93	0.00	0.00
Electrical Engineering Laboratory 1	42.68	43.29	14.02	0.00	0.00
Electrical Engineering Laboratory 2	55.14	33.51	11.35	0.00	0.00
Electrical Engineering Laboratory 3	6.59	62.87	29.34	1.20	0.00
Electrical Engineering Laboratory 4	44.91	47.90	7.19	0.00	0.00

The FYP performance results included in Table 6 indicate the compliance of the FYPs with the EAC and MQA requirements, which were at the core of the FYP committee's assessment. Considering the high percentage of the excellent and honours grades, the FYP was successful within both programmes.

Table 7 shows the performance of FKE students in the selected elective subjects. In this article, the authors consider only two relevant subjects in the conventional EE programme to compare them with selected elective subjects for BEKG.

Table 6: FYP.

	EE	BEKG
Excellent	26.67	31.21
Honours	44.00	33.76
Pass	22.77	21.02
Conditional pass	4.85	8.28
Fail	1.71	5.73

Table 7: Selected electrical engineering subjects in the conventional EE and the BEKG programme.

Subject	Industrial Power Electronics		Modern Electrical Drives		Industrial Control and Automation		Digital Control Systems		Power System Protection		High Voltage Engineering	
Programme	EE	BEK	EE	BEK	EE	BEK	EE	BEK	EE	BEK	EE	BEKG
Excellent	20.69	21.05	12.07	10.34	40.85	15.00	33.33	53.13	18.03	18.64	13.18	22.22
Honours	18.97	19.30	8.62	27.59	43.66	50.00	28.00	18.75	26.23	34.75	19.38	36.75
Pass	50.00	49.12	43.10	27.59	15.49	35.00	34.67	18.75	17.21	32.20	42.64	38.46
Conditional pass	10.34	10.53	29.31	34.48	0.00	0.00	4.00	6.25	25.41	10.17	19.38	2.56
Fail	0.00	0.00	6.90	0.00	0.00	0.00	0.00	3.13	13.11	4.24	5.43	0.00

When comparing the elective subjects in BEKG with the conventional EE programme's subjects, particularly in Power System Protection, it can be noticed that the number of students scoring at least a pass grade for BEKG is more than 85%. Moreover, the table reveals an improvement in the grades for BEKG in the Digital Control Systems subject, with a clear shift to the excellent grade. However, the progress of BEKG students in the remaining elective subjects shows a similar trend as that in the conventional EE programme. However, despite the mixed results in the elective subjects, BEKG appears the right direction for enhancing the Bachelor of EE curriculum.

This study also attempted to identify the difference in the mean grade performance of students in the two programmes. Analysis of variance was conducted to identify this difference using a 5% confidence interval. For a fair comparison of the statistical data, it was assumed that the standard deviation was known for a large and independent number of students from each cohort in each programme.

Table 8 shows the results from the *z*-test comparing the excellent grade in both programmes. The mean performance of BEKG surpasses that of the conventional EE programme in most categories, which is in line with the acceptance of the null hypothesis. Thus, there is enough evidence to conclude that the mean performance of students in BEKG is better than that in the conventional EE programme. The *z*-value for all the categories significantly impacts the programme performance, implying that students achieve better grades with a better curriculum structure.

Table 8: Comparison of the conventional EE and the BEKG programme based on the mean performance (standard deviation).

Data variable	BEKG	Conventional EE	*Z* value
Mathematics	3.10 (0.78)	2.94 (0.85)	9.1768
Basic science	2.53 (0.91)	2.14 (0.98)	4.561
Electrical	2.78 (0.96)	2.64 (0.97)	3.105
Laboratory	3.48 (0.46)	3.52 (0.46)	-4.6407
Elective	2.94 (0.80)	2.82 (0.90)	0.9957
Final Year Project	3.05 (0.96)	3.18 (0.69)	-2.1917

CONCLUSIONS

In this study was evaluated students' performance in the Bachelor of EE programme in the FKE, UTeM in Malaysia, indicating that the BEKG students' performance is better than those in the conventional EE programme in relation to the selected subjects. Also, the conducted comparative study based on statistical analysis supported all the findings. Thus, the BEKG new curriculum structure appears the right direction for advancing the Bachelor of EE curriculum structure.

Based on these findings, future studies may involve reviewing curricular structures of transdisciplinary courses and investigating intra-cohort students' performance in the BEKG programme.

In regard to the current study, the effectiveness of the discussed curricular structure regarding the EE students' performance is strongly supported by Aziah et al [11] and Nurdiana et al [15], who focussed on the measurement of PO attainment and team-teaching effectiveness. Finally, future work may develop a software tool that could facilitate students' performance evaluation and, hence, all courses' PO attainment.

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REFERENCES

1. Al-Nashash, H., Khaliq, A., Qaddoumi, N., Al-Assaf, Y., Assaleh, K., Dhaouadi, R. and El-Tarhuni, M., Improving electrical engineering education at the American University of Sharjah through continuous assessment. *European J. of Engng. Educ.*, 34, **1**, 15-28 (2009).
2. Penerbit Universiti, Academic Handbook, FKE, Session 2013/2014 UTeM, 1-167 (2013).
3. Penerbit Universiti, Academic Handbook, FKE, Session 2014/2015 UTeM, 1-165 (2014).
4. Letter of Request Approval, JPT(A)1000/011/012/01 Jld 4 (40), Meeting JKPT No 5/2013 on 25 July 2013.
5. Mutalib, A.A., Rahmat, R. A., Rashid, A. K. A., Suja, F. and Sahril, S., Measurement and evaluation of program outcomes in the civil engineering courses. *Procedia-Social and Behavioral Sciences*, 60, 333-342 (2012).
6. Faiz, M.M.U. and Almutairi, M.S., Assessment of student outcomes of an electrical and electronics engineering technology programme: a case study. *Global J. of Engng. Educ.*, 23, **3**, 231-239 (2021).
7. Dargham, J.A., Chekima, A., Yin, R.C.K. and Wong, F., A direct assessment method of the achievement of the PO from the courses outcomes. *Proc. 2013 IEEE 5th Conf. on Engng. Educ*., 131-135 (2013).
8. Bhuyan, M.H. and Tamir, A., Evaluating COs of computer programming course for OBE-based BSc in EEE program. *Inter. J. of Learning and Teaching*, 12, **2**, 86-99 (2020).
9. Bhuyan, M.H. and Khan, S.S.A., Assessing and evaluating the course outcomes of electrical circuit course for Bachelor of Science in electrical and electronic engineering program. *Inter. J. of Educational and Pedagogical Sciences*, *World Academy of Science, Engng. and Technol.*, 14, **12**, 1163-1171 (2020).
10. Tien, D.T.K., Namasivayam, S.N. and Ponniah, L.S., Transformative learning in engineering education: the experiential learning factor. *Global J. of Engng. Educ.*, 23, **3**, 223-230 (2021).
11. Aziah, K., Nur Ilyana, A.A., Azrita, A., Maaspaliza, A. and Mohd Luqman M.J., PO attainment measurement method for Bachelor of EE. *Proc. Innovative Teaching Research Day 2019*, Melaka, Malaysia (2019).
12. Aziah, K., Nur Ilyana, A.A. and Nor Aishah, M., Comparative study of curricular structures in Bachelor of Electrical Engineering UTeM. *Proc. Innovative Teaching Research Day 2018*, Melaka, Malaysia (2019).
13. Quality Management System Document MS ISO 9001: 2015 UTeM, UTEM(ISO)/PP/PPK03, Work Procedures A. Teaching, Learning and Research Management Process, 1 December 2018, https://www.utem.edu.my/intranet.html
14. Bilsel, A. and Oral, O., Curricular emphasis of mathematics and basic sciences in Turkish engineering schools. *Engng. Educ.: Rediscovering the Centre: Proc.*, 175 (1999).
15. Nurdiana, N., Aziah, K. and Jariah, M.J., Reliability analysis of the learning effectiveness scale in team-teaching for engineering courses in Universiti Teknikal Malaysia Melaka (UTeM). *Proc. Innovative Teaching Research Day 2019*, Melaka, Malaysia (2019).

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