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The Correlation Between Electrical Engineering Course Performance and Mathematics and Prerequisite Course Achievement

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ABSTRACT

Malaysia requires human capital with critical thinking and ability to solve problems to drive the country. These attributes are also required by the Engineering Accreditation Council (EAC), which stipulates that engineering students must have the ability to solve complex problems. Many electrical and electronics engineering courses require good understanding in mathematics to solve complex problems. In addition, some engineering courses have prerequisite courses, which students must complete before they can enrol in those courses in later semesters. Normally, prerequisite courses are fundamental courses and they play important roles in helping students understand the content of the course that requires the prerequisite. In this study, the relationship between student performance in electrical and electronics engineering courses and mathematics and prerequisite course achievement is identified. One mathematics and three engineering courses are used in this study, namely Calculus Vector (KQ1124), Circuit Theory 2 (KL1124), Electromagnetic Fields and Waves (KL2134) and Signal and System (KL2124). The Pearson correlation test using SPSS was used to identify the relationship between electrical and electronics engineering course performance with mathematics and prerequisite courses achievement. The results show that there is a strong positive relationship between engineering courses and previous mathematics achievement. A strong positive relationship also exists between performance in an engineering course and its prerequisite course.

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INTRODUCTION

Mathematical courses are important in the study of electrical and electronics engineering. Many electrical and electronics engineering courses such as Circuit Theory, Electromagnetic Fields and Waves, Signal and System and Digital Signal Processing require good understanding in mathematical courses such as Calculus Vector and Differential Equations. Furthermore, the Engineering Accreditation Council (EAC) has recently required engineering students to have the ability of solving complex problems, since most complex engineering problems require mathematics for their solution. Hence, mastery in mathematical courses is important for engineering students to achieve good grades in engineering programmes. Several studies have shown mathematics is important in engineering courses (Karen & Gergan, 2004; Uysal, 2012; Hsu, 2013). Aside from engineering, mathematical skills also impact student performance in other courses. Donovan and Wheland (2009) have shown that there is a relationship between mathematical ability and success and retention in chemistry courses. Mathematics is also important for solving physics problems (Wenno, 2015), and it is a predictor to physics students' performance (Awodun et al., 2013). Therefore, poor performance in mathematics may affect students' performance in engineering courses (Asshaari et al., 2011; Soheila et al., 2012).

Recently, students of the Department of Electrical, Electronics and Systems Engineering (DEES) in the Faculty of Engineering and Built Environment, Universiti Kebangsaan Malaysia (UKM) have shown a decline in their performance (Husain et al., 2011). This is not a situation that should occur because students who enrolled in this department obtained excellent results in their pre-university education. Additionally, the student selection scheme set by the university requires students who are highly qualified, not only in the academic field but also in co-curricular activities. Poor academic performance among university graduates is a serious issue because the community expects that these students will be knowledgeable individuals able to handle current development issues in society. Several studies have been done in an effort to improve students' performance. One of the efforts is the identification of possibly weak students at the early stage of their study by introducing an early test (Kamal et al., 2012). The early test questions cover basic mathematics and engineering knowledge. Students have to take the test in the first or second week of their study. Based on the test marks, possibly weak students (students with very low marks) can be identified. Hence, these possibly weak students can be closely monitored from the beginning of their study by their mentors, who are also lecturers of the department.

There may also be other reasons for the students' weak performance. One of these may be related to their weakness

in mathematics. A recent study shows that engineering students at the Faculty of Engineering & Built Environment, UKM are weak in mathematics (Ismail et al., 2011). The results show the overall mathematics performance of the whole faculty, which includes four different departments. Hence, no specific information on the mathematics performance of DEES students is available. Moreover, the study does not explore the relationship between mathematical achievement and performance in engineering courses. Therefore, the first aim of this study was to identify the relationship between electrical and electronics engineering performance with mathematical achievement. In this study, DEES students' performance in Calculus Vector (KQ1124), which is a mathematics course, was first compared with two engineering courses, Circuit Theory 2 (KL1124) and Electromagnetic Fields and Waves (KL2134) to find a relationship between them. Then, the relationship between Calculus Vector (KQ1124) and a third course, Signal and System (KL2124), was also tested. These three engineering courses were selected because the content of the courses requires Calculus Vector for analysis and problem solving.

Besides a good understanding in mathematics, some electrical and electronics engineering courses also require good understanding in fundamental courses, which are normally taught in the early semesters. Normally, the fundamental courses become prerequisite courses, which the students have to take before they can enrol in certain courses in later semesters. In order to understand the advance courses, students have to have mastery of fundamental knowledge. Therefore, mastery of prerequisite courses is important for the students to be able to achieve good grades in the advance courses. Previous studies showed that prerequisite courses have a relationship with students' performance in economics (Faridul et al., 2008; Peng, 2013) and nursing programmes (Alicia et al., 2003). Easter (2010) studied 10 contributing factors that affected students' chemistry grades, and the result showed that performance in prerequisite courses was the main factor. The same result was also evident for the management course, where the prerequisite affected performance in the Organisational Behavior course (Capehart & Bello, 2008). The same relationship may also exist in electrical and electronics engineering programmes. Therefore, the second aim of this study was to identify the relationship between performance in electrical and electronics engineering courses and the prerequisite course achievement. In this study, DEES students' performance in Circuit Theory 2 (KL1124) and Signal and System (KL2124) were compared to identify the relationship between them. Circuit Theory 2 (KL1124) is a prerequisite course for Signal and System (KL2124).

MATERIALS AND METHODS

This study was divided into two sections. The first section was to identify, if

any, the relationship between students' performance in mathematics and electrical and electronics engineering courses, while the second section was to identify the relationship between performance in an engineering course and its prerequisite course achievement. For the first section, final exam marks from one mathematics course, Calculus Vector (KQ1124), and two engineering courses, Circuit Theory 2 (KL1124) and Electromagnetic Fields and Waves (KL2134) were used. Calculus Vector was offered in Semester 1, Circuit Theory 2 in Semester 2 and Electromagnetic Fields and Waves in Semester 3. These three courses were chosen because Calculus Vector is required in solving complex problems in Circuit Theory 2 and Electromagnetic Fields and Waves. For the second section, the relationship between Circuit Theory 2 and Signal and System (KL2124) final marks were determined, where Circuit Theory 2 is the prerequisite course for Signal and System. As stated before, Circuit Theory 2 is offered in Semester 2, while Signal and System is offered in Semester 4.

For this study, only final exam marks were considered. This is because final exam questions cover the whole syllabus of the course. In addition, the final examination is an individual assessment where no group work is included in the evaluation. It is important in this study to use individual student assessment to compare the students' performance in each course. Furthermore, final exams are carried out in controlled environments, where students are seated at a certain distance from each other and have to answer all questions in a fixed period of time.

Student performance was rated based on the grades shown in Table 1. As discussed earlier, this study was only focussed on the final examination. For analysis, the grades are divided into six categories, namely Excellent, Good, Medium, Weak, Very Weak and Fail, as depicted in Table 1.

Table 1
Grades and Categories Based on Students' Marks

Grade	Marks	Category
A	80 - 100	Excellent
A-	75 – 79.9	Good
B+	70 – 74.9	
B	65 – 69.9	Medium
B-	60 – 64.9	
C+	55 – 59.9	Weak
C	50 – 54.9	
C-	45 – 49.9	Very weak
D+	40 – 44.9	
D	30 – 39.9	
E	0 – 29.9	Fail

The data analysis in this study used the Statistical Package for the Social Sciences (SPSS) software. In order to identify the relationship between students' performance in mathematics and engineering courses, and an engineering course and its prerequisite, the Pearson correlation test was used.

Participants

The participants of this study were students from the Department of Electrical,

Electronics & Systems Engineering, Faculty of Engineering and Built Environment, UKM. A total of 114 students from two batches participated in this study, of which the 2011 batch consisted of 56 students and the 2012 batch consisted of 58 students. Of the 2011 batch, 56.9% of the participants were male and 43.1% female, while the 2012 batch had an equal number of male and female participants. Tables 2 and 3 summarise the information on the gender of the participants involved in this study for both batches.

Table 2
Gender of the 2011 Batch

		Frequency	Percentage	Valid Percentage	Cumulative Percentage
Valid	Male	31	56.9	56.9	56.9
	Female	25	43.1	43.1	100.0
	Total	56	100.0	100.0	

Table 3
Gender of the 2012 Batch

		Frequency	Percentage	Valid Percentage	Cumulative Percentage
Valid	Male	29	50.0	50.0	50.0
	Female	29	50.0	50.0	100.0
	Total	58	100.0	100.0	

RESULTS AND DISCUSSION

The correlation between students' performance in mathematics and electrical and electronics engineering courses and the correlation between students' performance in an electrical and electronics engineering course and its prerequisite course are discussed separately in the following sub-sections.

Correlation between Performance in Mathematics and Engineering Courses

In order to identify the relationship between student performance in mathematics and engineering courses, the final marks from one mathematics subject, Calculus Vector (KQ1124) and two engineering courses, Circuit Theory 2 (KL1124) and Electromagnetic Fields and Waves (KL2134) were used as variables. The correlation tests were done separately, with null hypothesis for each test as follows:

H^{01}: There is no relationship between students' performance in Calculus Vector and Circuit Theory 2.

H^{02}: There is no relationship between students' performance in Calculus Vector and Electromagnetic Fields and Waves.

Tables 4 and 5 show the relationship between students' performance in Calculus Vector with Circuit Theory 2, and between Calculus Vector with Electromagnetic Fields and Waves for the 2011 and 2012 batches, respectively. As shown in Tables 4(a) and 4(b), the Pearson correlation coefficient values (*r*-values) of Calculus Vector and Circuit Theory 2 were 0.714 and 0.628, for the 2011 and 2012 batches, respectively. The *r*-values indicate that Calculus Vector and Circuit Theory 2 had a very strong positive relation. Therefore, students with good performance in Calculus Vector also gave good performance in Circuit Theory 2, while students with poor results in Calculus Vector performed poorly in Circuit Theory 2. The same relationship also appears true for Calculus Vector and Electromagnetic Fields and Waves, where the *r*-values for these courses were 0.662 and 0.575 for the 2011 and 2012 batches, respectively. Students with good performance in Calculus Vector also showed good performance in Electromagnetic Fields and Waves, while students with poor result in Calculus Vector also performed poorly in Electromagnetic Fields and Waves.

Another important parameter shown in Tables 4 and 5 is the significant value (*p*-value). The *p*-value for all variables in Tables 4 and 5 were zero, which indicates that both null hypotheses, *H01* and *H02* were rejected. Therefore, relationship exists between students' performance in Calculus Vector with Circuit Theory 2 and between Calculus Vector with Electromagnetic Fields and Waves.

The relationship between variables are also presented in scatter plots as shown in Figures 1 and 2. Figure 1 shows the scatter plots for correlation between students' performance in Calculus Vector and Circuit Theory 2 for the 2011 and 2012 batches. The correlation between students' performance in Calculus Vector and Electromagnetic Fields and Waves for both batches is shown in Figure 2. For each scatter plot, a best-fit line is drawn to see the relationship direction between the variables. All best-fit lines in Figures 1 and 2 show a positive direction, indicating that there was positive correlation between the variables.

Table 4
Correlation between Students' Performance in Calculus Vector (KQ1124) with Circuit Theory 2 (KL1124) for the (a) 2011 Batch and (b) 2012 Batch

		KL1124	KQ1124
KL1124	Pearson Correlation	1	.714**
	Sig. (2-tailed)		.000
	N	56	56
KQ1124	Pearson Correlation	.714**	1
	Sig. (2-tailed)	.000	
	N	56	56

**. Correlation is significant at the 0.01 level

(a) 2011 Batch

TABLE 4 (continue)

		KQ1124	KL1124
KQ1124	Pearson Correlation	1	.628**
	Sig. (2-tailed)		.000
	N	58	58
KL1124	Pearson Correlation	.628**	1
	Sig. (2-tailed)	.000	
	N	58	58

**. Correlation is significant at the 0.01 level

(b) 2012 Batch

Table 5

Correlation between Students' Performance in Calculus Vector (KQ1124) and Electromagnetic Fields and Waves (KL2134) for the (a) 2011 Batch and (b) 2012 Batch

		KQ1124	KL2134
KQ1124	Pearson Correlation	1	.662**
	Sig. (2-tailed)		.000
	N	56	56
KL2134	Pearson Correlation	.662**	1
	Sig. (2-tailed)	.000	
	N	56	56

**. Correlation is significant at the 0.01 level

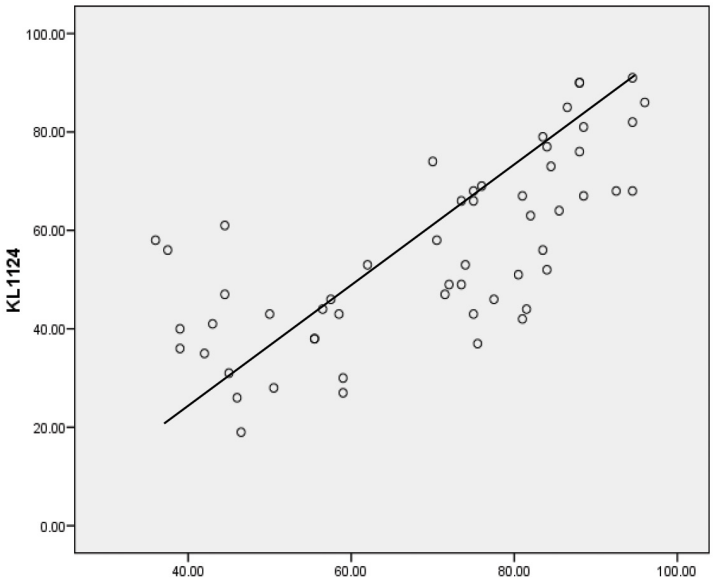
2011 Batch

		KQ1124	KL2134
KQ1124	Pearson Correlation	1	.575**
	Sig. (2-tailed)		.000
	N	58	58
KL2134	Pearson Correlation	.575**	1
	Sig. (2-tailed)	.000	
	N	58	58

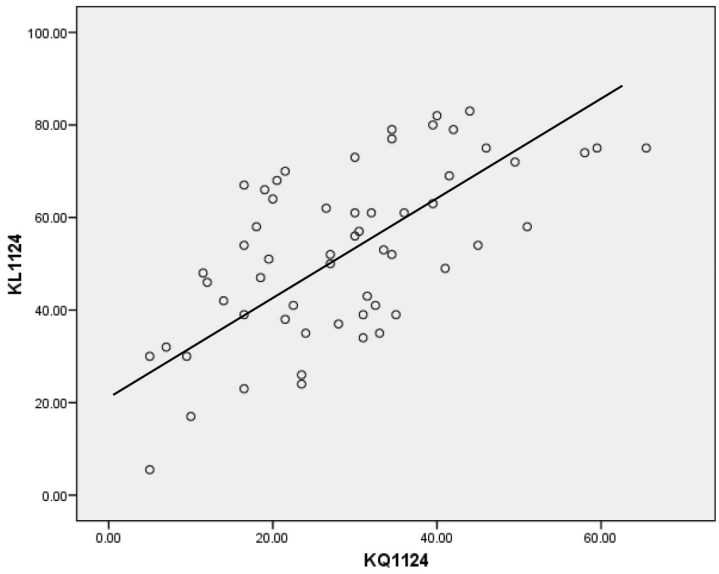
**. Correlation is significant at the 0.01 level

2012 Batch

A strong positive correlation between students' performance in Circuit Theory 2 and Electromagnetic Fields and Waves and Calculus Vector indicates strong relationship between mathematical achievement and student performance in electrical and electronics engineering courses. This is because problem solving in engineering courses requires good understanding of mathematics. Therefore, a strong foundation in mathematics is required in order to achieve good grades in electrical and electronics engineering courses.

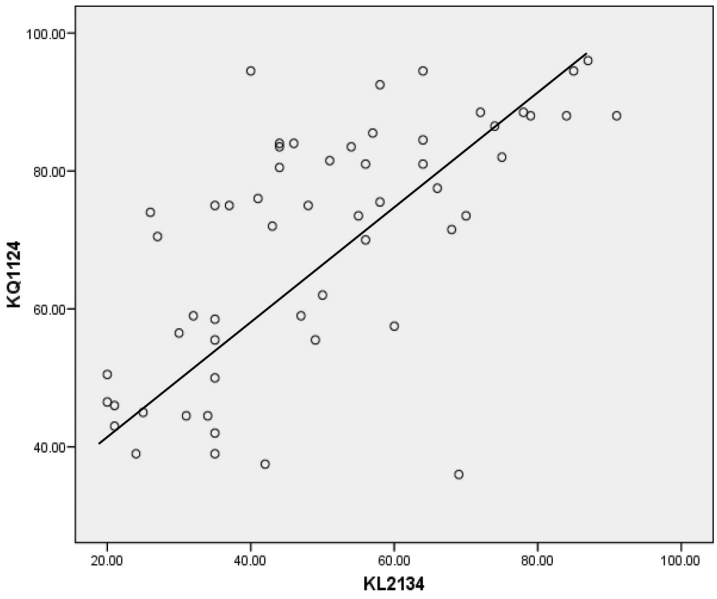


(a) 2011 batch

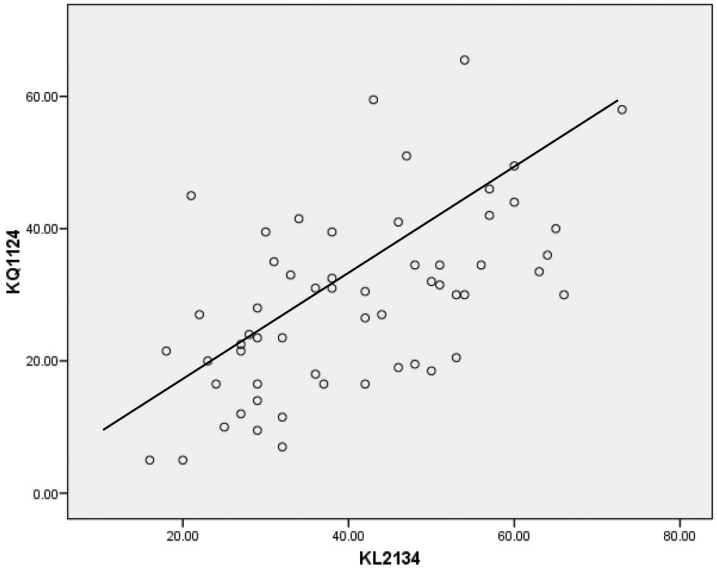


(b) 2012 batch

Figure 1. Scatter plots for the correlation between students' performance in Calculus Vector (KQ1124) and Circuit Theory 2 (KL1124) for the (a) 2011 batch and (b) 2012 batch.



(a) 2011 batch



(b) 2012 batch

Figure 2. Scatter plots for the correlation between Calculus Vector (KQ1124) and Electromagnetic Fields and Waves (KL2134) for the (a) 2011 batch and (b) 2012 batch.

For further analysis, the percentage of students' performance in Circuit Theory 2 and Electromagnetic Fields and Waves based on their Calculus Vector achievement was tabulated as shown in Table 6 and Table 7, respectively. The data are grouped into categories based on Table 1. The results showed that 50% of Excellent students in Calculus Vector achieved Excellent and Good grades in Circuit Theory 2. However, only 7.7% students with a Good grade in Calculus Vector achieved the Good grade in Circuit Theory 2. Meanwhile, 60.8% of students who failed Calculus Vector received Very weak or Fail on their Circuit Theory 2 tests.

Table 6
Percentage of Students' Performance in Circuit Theory 2 (KL1124) Based on Their Calculus Vector (KQ1124) Achievement

Category	KQ1124 (No. of students)	KL1124 (Percentage)					
		Excellent	Good	Medium	Weak	Very weak	Fail
Excellent	22	31.8%	18.2%	27.3%	13.6%	9.1%	0%
Good	13	0%	7.7%	30.8%	15.4%	46.2%	0%
Medium	2	0%	50.0%	0%	50.0%	0%	0%
Weak	12	0%	16.7%	0%	8.3%	58.3%	16.7%
Very weak	37	5.4%	18.9%	16.2%	18.9%	35.1%	5.4%
Fail	28	0%	3.6%	17.9%	17.9%	42.9%	17.9%

As shown in Table 7, 40.9% of Excellent students in Calculus Vector obtained Excellent and Good grades in the Electromagnetic Fields and Waves course. However, only 7.7% of the Good grade students in Calculus Vector also achieved the Good grade in Electromagnetic Fields and Waves. Meanwhile, 92.8% of students who failed Calculus Vector got Very weak or Fail grades in Electromagnetic Fields and Waves.

Table 7
Percentage of Students' Performance in Electromagnetic Fields and Waves (KL2134) Based on Their Calculus Vector (KQ1124) Achievement

Category	KQ1124 (No. of students)	KL2134 (Percentage)					
		Excellent	Good	Medium	Weak	Very weak	Fail
Excellent	22	18.2%	22.7%	13.6%	22.7%	22.7%	0%
Good	13	0%	7.7%	15.4%	23.1%	38.5%	15.4%
Medium	2	0%	0%	0%	100%	0%	0%
Weak	12	0%	8.3%	8.3%	0%	75.0%	8.3%
Very weak	37	0%	0%	18.9%	21.6%	40.5%	18.9%
Fail	28	0%	0%	0%	7.1%	35.7%	57.1%

The results in Table 6 and Table 7 suggest that students must score an A grade in Calculus Vector in order to obtain a Good grade in Circuit Theory 2 and Electromagnetic Fields and Waves. A fail in Calculus Vector results in the high possibility of students failing or obtaining a very weak grade in both Calculus Vector and Electromagnetic Fields and Waves.

Correlation between Performance in an Engineering Course and Its Prerequisite Course

In addition to the relationship between the mathematics and engineering courses, this study also looked at the relationship between students' performance in the electrical and electronics engineering course and its prerequisite course. For this study, Signal and System (KL2124) and its prerequisite course Circuit Theory 2 (KL1124) were chosen as the variables. In addition, the mathematics course Calculus Vector (KQ1124) was also included in the correlation test because both engineering courses require mathematics in solving complex problems. Table 8 shows the Pearson correlation test result for these three courses.

As shown in Table 8, the *r*-values for Circuit Theory II and Signal and System were 0.762 and 0.733 for the 2011 and 2012 batches, respectively. The results showed a strong positive correlation between the engineering course and its prerequisite course. In addition, the table also shows a strong positive correlation between Signal and System and Calculus Vector, where the *r*-values were 0.729 and 0.598 for the 2011 and 2012 batches, respectively. This also supports the results in the earlier section, where students' performance in engineering courses was related to their achievement in mathematics.

Table 8
Correlation Between Students' Performance in Calculus Vector (KQ1124), Circuit Theory 2 (KL1124) and Signal and System (KL2124) for the (a) 2011 Batch and (b) 2012 Batch

		KQ1124	KL1124	KL2124
KQ1124	Pearson Correlation	1	.714**	.729**
	Sig. (2-tailed)		.000	.000
	N	56	56	56
KL1124	Pearson Correlation	.714**	1	.762**
	Sig. (2-tailed)	.000		.000
	N	56	56	56
KL2124	Pearson Correlation	.729**	.762**	1
	Sig. (2-tailed)	.000	.000	
	N	56	56	56

**. Correlation is significant at the 0.01 level (2-tailed)

(a) 2011 Batch

TABLE 8 (continue)

		KQ1124	KL1124	KL2124
KQ1124	Pearson Correlation	1	.628**	.598**
	Sig. (2-tailed)		.000	.000
	N	58	58	58
KL1124	Pearson Correlation	.628**	1	.733**
	Sig. (2-tailed)	.000		.000
	N	58	58	58
KL2124	Pearson Correlation	.598**	.733**	1
	Sig. (2-tailed)	.000	.000	
	N	58	58	58

**. Correlation is significant at the 0.01 level (2-tailed)

(b) 2012 Batch

Table 9 shows the percentage of students' performance in Signal and System based on their prerequisite course achievement, which is Circuit Theory 2 for both the 2011 and 2012 batches. The performance is again grouped into categories based on Table 1. About 88.8% of students with Excellent grade in the prerequisite course achieved Good and Excellent grades in Signal and System. Meanwhile, 50% of students with Good grade in Circuit Theory 2 attained Good and Excellent grades in Signal and System. These results showed that students with Excellent and Good grades in the prerequisite course had a very good chance of obtaining the Good grade in the course that needed the prerequisite. This result suggested that the students should score at least 70 marks or grade B+ in Circuit Theory 2 in order to get a Good grade in Signal and System.

On the other hand, 62.5% of Very weak students in Circuit Theory 2 got Weak and Very weak grades in Signal and System, and 25% of them failed the course. About 44.4% of Fail students in the prerequisite course also failed in Signal and System, and 22.2% of them achieve the Very weak grade. Therefore, students who failed the prerequisite course had a very high possibility of failing or getting a very weak grade in the course that needs the prerequisite.

Table 9
Percentage of Students' Performance in Signal and System (KL2124) Based on Their Prerequisite Course Achievement

Category	KL1124 (No. of students)	KL2124 (Percentage)					
		Excellent	Good	Medium	Weak	Very weak	Fail
Excellent	9	44.4%	44.4%	11.1%	0%	0%	0%
Good	16	25.0%	25.0%	31.3%	18.8%	0%	0%
Medium	21	14.3%	9.5%	28.6%	19.0%	23.8%	4.8%
Weak	19	5.3%	10.5%	36.8%	31.6%	15.8%	0%
Very weak	40	0%	0%	12.5%	22.5%	40.0%	25.0%
Fail	9	0%	0%	0%	33.3%	22.2%	44.4%

CONCLUSION

This study presents a relationship between students' performance in mathematics with electrical and electronics engineering courses and between an electrical and electronics engineering course and its prerequisite courses. One mathematics and three electrical and electronics engineering courses were chosen as variables in this study. They are Calculus Vector (KQ1124), Circuit Theory 2 (KL1124), Electromagnetic Fields and Waves (KL2134) and Signal and System (KL2124). The SPSS Pearson correlation test was used to get the relationship between the variables. The results showed that there was a strong positive relationship between students' achievement in mathematics and their performance in engineering courses. A strong positive relationship also existed between students' performance in an engineering course and its prerequisite course. Therefore, in order to obtain good grades in engineering courses, students must achieve good results in mathematics and fundamental engineering courses, which become prerequisites to other courses. Improvement to teaching and learning is essential for the mathematics and fundamental engineering courses to help students achieve good results in these courses, and subsequently perform well in all the other engineering courses. These students achieved good grades in their pre-university education, implying that they had the ability to succeed in their engineering studies.

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