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Identifying Common Engineering Mathematics Topics for Innovative Learning of Engineering Mathematics

[1]N. Lohgheswary, [1]Z.M. Nopiah, [2]E. Zakaria, [3]A.A. Aziz and [4]S. Salmaliza
[1]Centre of Engineering and Built Environment Education Research, Faculty of Engineering and Built Environment, Universiti Kebangsaan Malaysia, Bangi, 43600 Selangor Darul Ehsan, Malaysia
[2]Faculty of Education, Universiti Kebangsaan Malaysia, Bangi, 43600 Selangor Darul Ehsan, Malaysia
[3]Faculty of Computing and IT, King Abdulaziz University, Jeddah, 80200 Saudi Arabia
[4]Centre of Engineering Education Research, Faculty of Engineering and Built Environment, SEGi University, Kota Damansara 47810, Selangor Darul Ehsan, Malaysia
lohgheswarynagarethinam@gmail.com

Abstract: A need urge to investigate the curriculum of Engineering Mathematics to identify the common Engineering Mathematics topics between Universiti Kebangsaan Malaysia and some other world top universities. This study aimed to introduce an innovative way for learning Engineering Mathematics. The 59 universitie's vector calculus syllabi, 61 universitie's Linear algebra syllabi and 60 universitie's differential equation syllabi were compared with UKM's syllabus. Line integral, double integral, green's theorem and triple integral, matrix and basic operation, vector space, eigen value and eigen vector, first-order differential equation, higher-order differential equation and laplace transform are popular topics in Engineering Mathematics. Lab sessions will be introduced in these topics to increase students understanding in the subject and to improve their performance.

Key words: Engineering Mathematics, vector calculus, Linear algebra, differential equation, syllabus content

INTRODUCTION

Engineering Mathematics is a need for engineering, science and technology fields. Engineering educators need to ensure that engineering students have a solid foundational understanding of mathematical content and knowledge. The Engineering Mathematics concepts are essential for other engineering subjects in undergraduate engineering degree course.

The student entry competencies in basic mathematical skills were examined for a decade (Lawson, 2003). The study showed a significant decline in many mathematical skills among the students. Mathematics pre-test for first year engineering students showed that students are still lacking in knowledge in some topics in mathematics which are essential for further engineering subjects (Othman *et al*., 2010).

This study aims to review UKM's vector calculus syllabus, Linear algebra syllabus and differential equation syllabus with other public universitie's syllabi and some world top universitie's syllabi to identify the important topics in a 14 weeks curriculum. So far, no research has been conducted in this university to identify common topics for computing application within the university. This pioneer research would help other researchers to create lab manuals for Engineering Mathematics subjects.

MATERIALS AND METHODS

In UKM, vector calculus, Linear algebra and differential equations are common Engineering Mathematics subjects in four departments. The departments are the Department of Electrical and Electronics Engineering, Department of Mechanical Engineering, Department of Civil Engineering and Department of Chemical Engineering.

The first semester students studying vector calculus have to take the course for a period of 14 weeks and this 4 credit hour subject has to be taken by the engineering students. The weekly syllabus for vector calculus subject in UKM is given in Table 1. Linear algebra is the second semester Engineering Mathematics subjects taken by the students. The detail of weekly syllabus is listed in Table 2. Differential equations is the third semester

Corresponding Author: N. Lohgheswary, Faculty of Engineering and Built Environment, SEGi University, 47810 Kota Damansara, Selangor Darul Ehsan, Malaysia, lohgheswarynagarethinam@gmail.com

Table 1: The weekly syllabus of vector calculus in UKM

Weeks	Description
1	Understanding bacis complex number and hyperbolic function
2	Vector functions
3	Motion on a curve. Curvature and components of accerleration
4	Partial derivatives. Directional derivatives
5	Tangent planes and normal lines. Divergence and curl
6	Line integrals. Independence of path
7	Double integrals. Double integrals in polar coordinates
8	Green's theorem. Surface integrals
9	Stoke's theorem
10	Triple integrals
11	Divergence theorem. Change of variables in multiple integrals
12	Sets in the complex plane. Functions of a complex variable. Cauchy-Riemann equations
13	Contour integrals. Cauchy-Goursat theorem
14	Independence of path. Cauchy's integral formulas

Table 2: The weekly syllabus of Linear algebra in UKM

Weeks	Description
1	Matrix and basic operation. Gaussian elimination, determinant-cofactor expansion, row reduction and Cramer's rule, inverse matrix
2	Applications: Linear system and Leontif input-output models
3	Vector space and subspace. Linear independence, basis, dimension, change of basis
4	Row space, column space, null space, rank, nullity
5	Matrix transformations. Applications: geometry of matrix operator, dynamical systems and Markov chain
6	Eigenvalue and eigenvector. Application-differential equation
7	Inner product spaces-Gram-schmidt process. Applications-least square fitting and function approximation
8	Diagonalization and quartic forms
9	Linear transformation-isomorphism, composition and inverse transformation
10	LU-Decomposition, power method. Applications-numerical method
11	Sequence, infinite series, partial sum, types of series: geometric series, harmonic series, P-series, alternating series
12	Convergence-integral test, comparison test, ratio test, root test
13	Power series, radius of convergence, taylor series, Mac Lauren series
14	Fourier series-cosine and sine series

Table 3: The weekly syllabus of Differential Equations in UKM

Weeks	Description
1	Introduction to differential equations
2	First-order differential equations and modeling with systems of first-order DEs
3	First-order differential equations and modeling with systems of first-order DEs
4	First-order differential equations and modeling with systems of first-order DEs
5	Higher-order differential equations and modeling with systems of higher-order DEs
6	Higher-order differential equations and modeling with systems of higher-order DEs
7	Higher-order differential equations and modeling with systems of higher-order DEs
8	The lapalce transform
9	The lapalce transform
10	Series solutions of Linear differential equations
11	Orthogonal functions and fourier series
12	Boundary value-problems in rectangular coordinates
13	Boundary value-problems in rectangular coordinates
14	Integral transforms

Engineering Mathematics subject taken by the students. The detail of weekly syllabus is listed in Table 3. The UKM vector calculus syllabus is compared with that from 59 world top universities. Twenty universities from the United States, 20 universities from the United Kingdom, 10 universities from Ocenia, 4 universities from Asia and 5 universities from Malaysia are chosen for this study. The UKM Linear algebra syllabus is compared with 61 world top universities. Twenty universities from the United States, 20 universities from the United Kingdom, 10 universities from Ocenia, 6 universities from Asia and 5 universities from Malaysia are chosen for this study. The UKM differential equations syllabus is compared with 60 world top universities. Twenty universities from the United States, 20 universities from the United Kingdom, 10 universities from Ocenia, 5 universities from Asia and 5 universities from Malaysia are chosen for this study.

As the first step, the internet website of each university was explored to get into the engineering faculty and then to the engineering department. Then the name list of the subject was browsed to find out how many engineering mathematics subjects are offered. Then each subject syllabus was explored thoroughly to find the match between UKM's vector calculus syllabus content. A table was prepared for

each subject. If the other universitie's syllabi have the same weekly topic as UKM's, 'x' will be marked.

Once the table was completed for the subject, the total 'x' for 59 universities for week 1 was calculated. For example, 'Understanding basic complex number and hyperbolic function' is taught by 30 universities out of 59 universities. Hence, the percentage for that topic is being calculated in the following way:

$$\frac{30}{59}\times 100 = 51\%$$

In the same way, the other 13 weekly topic percentages have been calculated. These steps are repeated for Linear algebra and differential equations subjects.

RESULTS AND DISCUSSION

Table 4 shows the percentages for the weekly topic for vector calculus. Table 5 shows the percentages for the weekly topic for Linear algebra subject. Table 6 shows the percentages for the weekly topic for differential equations subject.

From Table 4, a bar chart plot to represent the distribution percentages of weekly topic of vector calculus. Figure 1 shows the distribution of weekly topics for vector calculus. The benchmark line set up is at 50%. This means if any of the weekly topic distribution is 50% or more than 50%, then it is considered as an important topic of that subject.

For vector calculus subject, topics from weeks 1, 2, 4, 6, 7, 8, 9, 10 are more than the benchmark. Therefore, understanding basic complex number and hyperbolic function, vector functions, partial derivatives, directional derivatives, Line integrals, Independence of path, double integrals, double integrals in polar coordinates, green's theorem, surface integrals, Stoke's theorem and triple integrals are common topics between UKM and other universities.

From Table 5, a bar chart plot to represent the distribution percentages of weekly topic of Linear algebra. Figure 2 shows the distribution of weekly topics for Linear algebra.

Table 4: Percentage of weekly topic for vector calculus

Weeks	Total	Percentage
1	30	51
2	40	68
3	13	22
4	38	64
5	28	47
6	36	61
7	45	76
8	38	64
9	32	54
10	45	76
11	24	41
12	11	19
13	6	10
14	8	14

Table 5: Percentage of weekly topic for Linear algebra

Weeks	Total	Percentage
1	49	80
2	25	41
3	34	56
4	20	33
5	S28	47
6	19	31
7	49	80
8	16	26
9	26	43
10	4	7
11	17	28
12	17	28
13	27	44
14	25	41

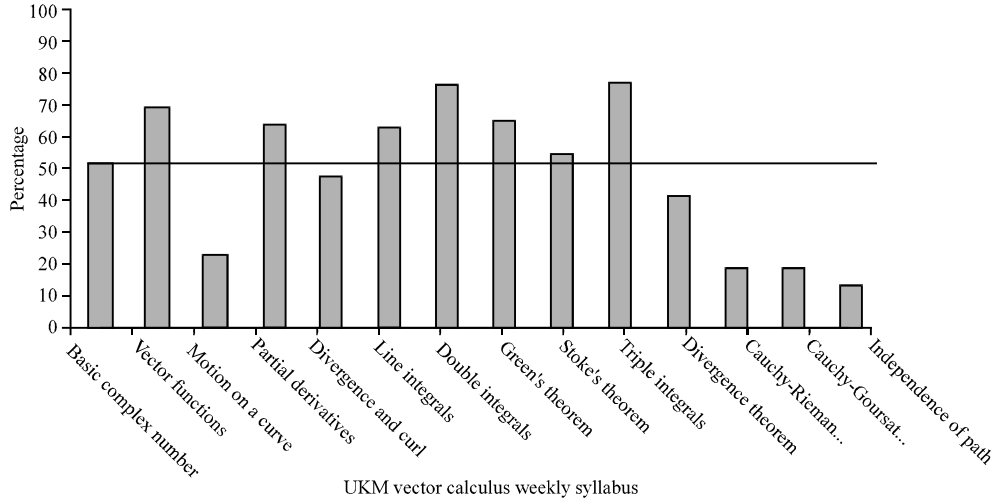

Fig. 1: Distribution of weekly Linear algebra to1pics

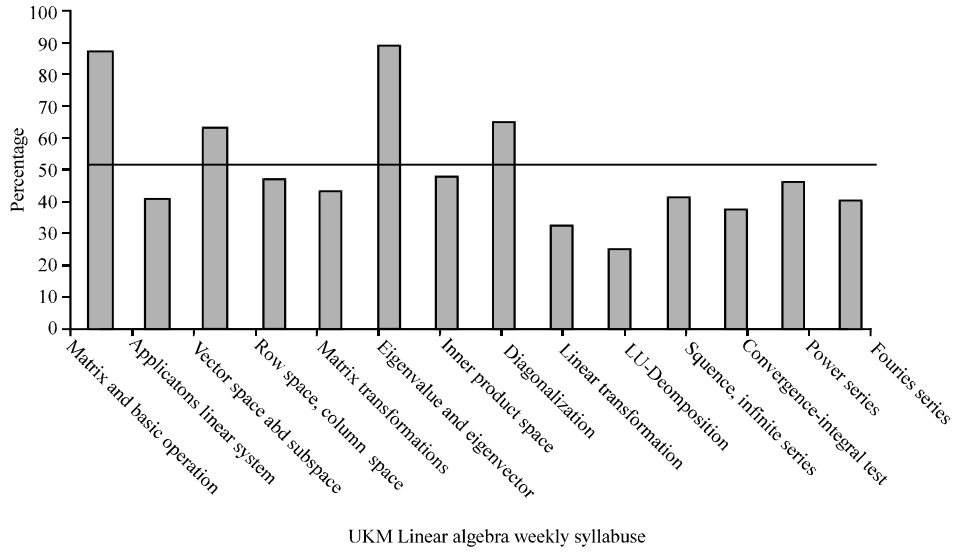

Fig. 2: Distribution of weekly topics

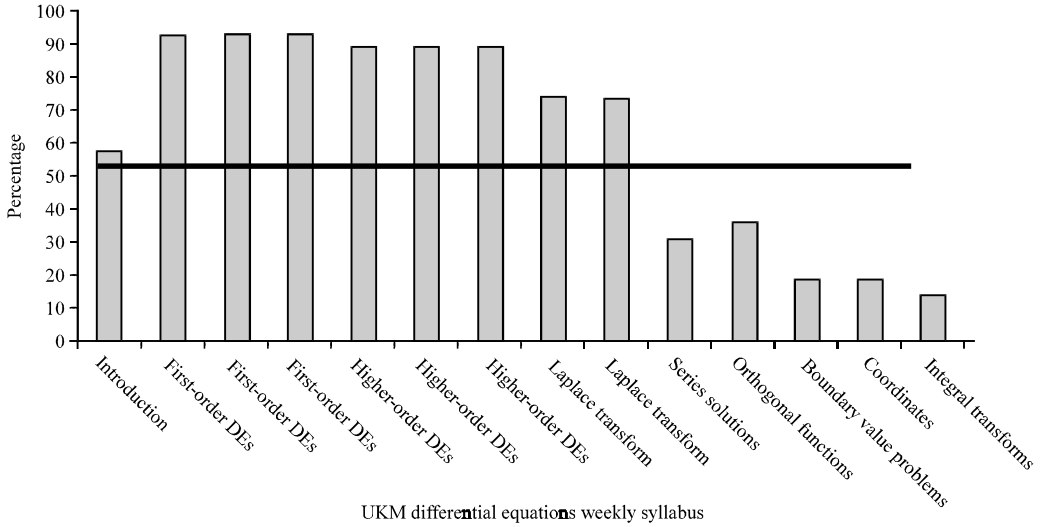

Fig. 3: Distribution of weekly differential equations topics

For Linear algebra subject, topics from weeks 1, 3 and 6 are higher than the benchmark. So, matrix and basic operation, gaussian elimination, determinant-cofactor expansion, row reduction and Cramer's rule, inverse matrix, vector space and subspace, Linear independence, basis, dimension, change of basis, eigenvalue and eigenvector and application-differential equation are common topics for UKM and other universities in the Linear algebra subject. From Table 6, a bar chart is drawn to represent the distribution percentages of weekly topic of differential equations. Figure 3 show the distribution percentages of weekly topic of differential equations.

Table 6: Percentage of weekly topic for differential equations

Weeks	Total	Percentage
1	34	57
2	55	92
3	55	92
4	55	92
5	53	88
6	53	88
7	53	88
8	44	73
9	44	73
10	18	30
11	21	35
12	11	18
13	11	18
14	8	13

Table 7: Summary of the important topics in Engineering Mathematics

Subject	Important topics/researcher	Godarzi *et al.* (2009)	Noinang *et al.* (2009)	Adair and Jaeger (2014)	Charney (2008)	Kilicman *et al.* (2010)	Van *et al.*	Maat and Zakaria (2011)	Zeynivannezad (2014)
Vector calculus	Understanding basic complex number and hyperbolic function								
	Vector functions								
	Partial derivatives. Directional derivatives								
	Line integrals. Independence of path		x						
	Double integrals. Double integrals in polar coordinates	x							
	Green's theorem. Surface integrals		x						
	Stoke's theorem			x					
	Triple integrals		x						
Linear algebra	Matrix and basic operation. Gaussian elimination, determinant-cofactor expansion, row reduction and Cramer's rule, inverse matrix		x		x		x		
	Vector space and subspace. Linear independence, basis, dimension. Change of basis						x		
	Eigenvalue and eigenvector					x			
	Application-differential equations								
Ordinary differential equations	Introduction to differential equations								
	first-order differential equations and modeling with systems of first-order DEs							x	x
	higher-order differential equations and modeling with systems of higher-order DEs								x
	The Laplace transform								x

For differential equations subject, topics from weeks 1, 2, 5 and 8 are more than the benchmark. Introduction to differential equations, first-order differential equations and modeling with systems of first-order DEs, higher-order differential equations and modeling with systems of higher-order DEs and the Laplace transform are considered common topics between UKM and other universities.

Several research has been conducted in applying computing tools in some od the important topics in Engineering Mathematics. For instance Maple 12 was used in teaching-learning of double integral (Godarzi *et al*,. 2009). Maple worksheets created to aid in teaching of line integrals, surface integrals and volume integrals (Noinang *et al*., 2009). Stoke's theorem was applied in conducting laboratory session in mathematica for engineering students (Adair and Jaeger, 2014). Mathcad was implemented as a visual matrix manipulation tool (Charney, 2008). Tutorials in plotting eigenvector and compute eigenvalues via. Maple was introduced (Kilicman *et al*., 2010). A system using Maple to solve problem of matrix determinant and vector space was created (Do Van and Kim, 2011). First-order differential equations using Maple was implemented to give students a better understanding of the subject (Maat and Zakaria, 2011). Teaching experiments via. maxima was conducted for first-order, second-order, higher-order differential equations and laplace transform (Zeynivannezhad, 2014). Table 7 shows a summary of the important topics in Engineering Mathematics and the list of researcher who contributed towards using various kinds of software.

The studied showed a significant difference towards student's positive attitude and their better performance in learning. Software tools helped to visualize difficult concepts and able to save ample of time spent on tedious calculations. Mathematica, Maple, mathcad, maxima are some of the technological tools used to enhanced the learning of Engineeering Mathematics.

CONCLUSION

As Engineering Mathematics serves as the basis for all engineering studies, it is important to grasp the fundamental knowledge of Engineering Mathematics. UKM's vector calculus, Linear algebra and differential equations syllabus are compared with world top universities and the important topics for software computing were identified. Line integral, double integral, Green's theorem, triple integral, matrix and basic operation, vector space, eigen value and eigen vector, first-order differential equations, higher-order differential equations, Laplace transform are important topics in vector calculus, Linear algebra and differential equations. To justify the results above, the research done on this topic over a 10 years period was illustrated. Different software had been implemented in learning Engineering Mathematics. There are many other topics which are not explored using software tools. A different kind of software can also be used to conduct teaching experiments using these important topics in Engineering Mathematics. These topics can also be used to create pre-test and post-test

questions in a study. It is hope that this study would benefit future researcher to explore the usage of software in engineering application particularly related with Engineering Mathematics.

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