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Identify Challenging Engineering Mathematics Topics from Exam Questions

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Abstract: Mathematics and Engineering are the key elements in STEM (Science Technology Engineering Mathematics education. Thus, a strong foundation in Engineering Mathematics will ensure a good understanding of Engineering concepts. Yet, some student still find Engineering Mathematics as a challenging subject. Thus, the objective of this study is to identify the challenging Engineering Mathematics topics from exam questions. The final exam questions from Engineering Mathematics I and II, subjects from a private university in Malaysia was analyzed for this study. Exam results were analyzed in Rasch Model. Differentiation using first principle, differentiating functions, finding minimum value, solving system of linear equations using inverse matrix, finding unit vector and finding the root of complex numbers are the challenging topics in Engineering Mathematics I. Integration of exponential function, integration by substitution, first order differential equation, using Laplace transform to solve first order differential equation, sketch graph and Fourier series are the challenging topics in Engineering Mathematics II. Thus, the lecturer who will be teaching in the upcoming semester can emphasize more on these challenging topics. Identifying challenging topics in Engineering Mathematics will prevent the students from failing the other engineering subjects in the subsequent years.

Key words: Engineering Mathematics I, Engineering Mathematics II, analyzing, exam questions, topics, subsequent

INTRODUCTION

Mathematics and Engineering are the key element in STEM (Science Technology Engineering Mathematics) education. Thus, a strong foundation in Engineering Mathematics will ensure a good understanding of Engineering concepts. Yet, some students still find challenging in studying Engineering Mathematics.

Poor performance in Mathematics became a global issue among stakeholders at tertiary level, especially, in Engineering Mathematics (Godwin and Chinedu, 2013). A study was conducted to investigate the underlying causes of engineering students in four academic sessions. Factors that contribute to poor performance are poor learning environment and poor coordination of time. Separating lesson timetable to two or more groups, fair evaluation and fair marking on exam scripts can overcome the weaknesses. Learning in small groups can increase interaction between teachers and students. Students can also learn from discussions with each other.

Another factor for poor performance in Mathematics is the teachers who did not have the potential to teach mathematical subjects (Jameel and Ali, 2016). Teachers need to change their teaching methods. Lecturers are also encouraged to improve the use of hard copy materials in Mathematics and calculus (Eng *et al*., 2008). Teachers need to undergo workshops or briefings to find alternative ways to teach. Problem-based teaching, project-based teaching, technology-based teaching are among other ways to teach. Teachers can also give questions to students at the end of the lesson, so, they can think and answer the questions at home.

Early identification of the challenging topics in Engineering Mathematics can be helpful for the other lecturers who is going to teach for the other batches

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wehreby the lecturer can put more effort to emphasize the challenging topics. In addition, the lecturers can give more questions to try during the class, so that, the students could understand the topics better. Thus, the objective of this study is to identify the challenging topics from Engineering Mathematics I and II exam questions.

MATERIALS AND METHODS

This study involves a private university in Malaysia which offers 4 years engineering programmes. Engineering Mathematics I (EEM3113) and Engineering Mathematics II (EEM3213) are the Engineering Mathematics subjects taken in the semester I and II, respectively. These 2 subjects are taken by students from the Department of Electronic and Electrical Engineering, Department of Chemical Engineering, Department of Mechanical Engineering and Department of Civil Engineering. Engineering Mathematics I is a pre-requisite for Engineering Mathematics II.

The students undergo a teaching of 14 weeks in a semester. Students will have a mid-term test and an assignment to be submitted as the coursework component. The weightage for the test is 20%, the weightage for the assignment is 20% whereas the weightage for the final examination is 60%. The total percentage of the test, assignment and final examination will determine the grade of students for the Engineering Mathematics subjects.

The final examination for Engineering Mathematics I was conducted in session 2017/2018. A total of 4 subjective questions with several parts were designed and validated by a lecturer. There is a total of 23 questions altogether. The duration of the final examination is 2 h and the total marks is 100. A total of 137 students sat for the final exam of Engineering Mathematics I. There are 25 Chemical Engineering students, 32 Electronic and Electrical Engineering students, 43 Mechanical Engineering students and 37 Civil Engineering students who took the final examination.

Table 1 shows the students profile who took the final exam of Engineering Mathematics I. Table 2 shows the course outcomes for Engineering Mathematics I subject. Table 3 shows the details of the final exam questions mapping to the level of Bloom taxonomy and the course outcome.

Table 1: Student's profile

Departments	No. of students
Chemical Engineering	25
Electronic and Electrical Engineering	32
Mechanical Engineering	43
Civil Engineering	37

The final examination for Engineering Mathematics II was conducted in Session 2018/2019. A total of 4 subjective questions with several parts were designed and validated by a lecturer. There is a total of 15 questions altogether. The duration of the final examination is 2 h and the total marks is 100. A total of 34 students sat for the final exam of Engineering Mathematics II. There are 10 Chemical Engineering students, 3 Electronic and Electrical Engineering students, 15 Mechanical Engineering students and 6 Civil Engineering students who took the final examination. Table 4 shows the students profile who took the final exam of Engineering Mathematics II. Table 5 shows the

Table 2: Course outcomes for Engineering Mathematics I subject

Course Outcome (CO)	Descriptions
1	Solve algebra problems including logarithm and exponential equations, hyperbolic and inverse hyperbolic functions
2	Apply polar form in De Moivre's Theorem and roots of complex numbers
3	Solve matrix algebra including linear system of equations, eigenvalues and eigenvectors
4	Solve differentiation and its application in vectors

Table 3: Entry number for each question

Questions	Bloom taxonomy	Course Outcome (CO)
1a (i)	Application	1
1a (ii)	Application	1
1b (i)	Comprehension	1
1b (ii)	Application	1
1c (i)	Comprehension	1
1c (ii)	Application	1
2a	Knowledge	2
2b	Application	2
2c	Application	2
2d (i)	Comprehension	2
2d (ii)	Application	2
3a (i)	Knowledge	3
3a (ii)	Knowledge	3
3a (iii)	Application	3
3b (i)	Application	3
3b (ii)	Application	3
3c	Analysis	3
4a	Analysis	4
4b	Application	4
4c (i)	Application	4
4c (ii)	Application	4
4c (iii)	Application	4
4c (iv)	Application	4

Table 4: Student's profile

Departments	No. of students
Chemical Engineering	10
Electronic and Electrical Engineering	3
Mechanical Engineering	15
Civil Engineering	6

Table 5: Course outcomes for Engineering Mathematics II subject

Course outcomes	Descriptions
1	Solve partial differentiation's applications
2	Solve integration problems by various methods
3	Apply Calculus in Maclaurin, Taylor and Fourier series
4	Solve differential equations, Laplace transform and inverse Laplace transform

course outcomes for Engineering Mathematics II subject. Table 6 shows the details of the final exam questions mapping to the level of Bloom taxonomy and the course outcome.

Table 6: Entry number for each question

Questions	Bloom taxonomy	Course Outcome (CO)
1a (i)	Analysis	1
1a (ii)	Comprehension	1
2a (i)	Application	2
2a (ii)	Application	2
2a (iii)	Application	2
2a (iv)	Application	2
2b	Analysis	2
3a	Application	3
3b (i)	Knowledge	3
3b (ii)	Knowledge	3
3b (iii)	Knowledge	3
3c	Comprehension	3
4a (i)	Comprehension	4
4a (ii)	Application	4
4b	Knowledge	4

RESULTS AND DISCUSSION

All the pre-post test marks were entered in Excel *prn format and transferred to WINSTEPS (Linacre, 2008). The WINSTEPS analysis is done using Rasch Model. WINSTEPS provides details on the summary statistics for person, summary statistics for item, item statistics, item dimensionality and person-item distribution map.

Engineering Mathematics I summary statistics for person: The summary of the statistical results for the measurement of person is given in Fig. 1. Person represents the students who sat for the Engineering Mathematics I final exam. The Cronbach alpha shows that the test reliability is 0.93. The person reliability is 0.76 (Fig. 1 and 2).

Figure 1, the person separation is 1.78 logit. Therefore, the students can be divided into two groups.

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  SUMMARY OF 137 MEASURED (EXTREME AND NON-EXTREME) Person
-------------------------------------------------------------------------------
|          TOTAL                         MODEL         INFIT         OUTFIT    |
|          SCORE     COUNT     MEASURE   ERROR      MNSQ   ZSTD   MNSQ   ZSTD |
|-----------------------------------------------------------------------------|
| MEAN      69.9      23.0        -.02     .22                                 |
| S.D.      26.6        .0         .70     .25                                 |
| MAX.     115.0      23.0        2.44    1.56                                 |
| MIN.      23.0      23.0       -2.04     .13        .45   -2.6    .30   -2.2 |
|-----------------------------------------------------------------------------|
| REAL RMSE    .34 TRUE SD     .61  SEPARATION  1.78  Person RELIABILITY  .76 |
|MODEL RMSE    .34 TRUE SD     .61  SEPARATION  1.82  Person RELIABILITY  .77 |
| S.E. OF Person MEAN = .06                                                   |
-------------------------------------------------------------------------------
Person RAW SCORE-TO-MEASURE CORRELATION = .93
CRONBACH ALPHA (KR-20) Person RAW SCORE "TEST" RELIABILITY = .93
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Fig. 1: Summary statistics for person

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SUMMARY OF 23 MEASURED (NON-EXTREME) Item
-------------------------------------------------------------------------------
|          TOTAL                         MODEL         INFIT         OUTFIT    |
|          SCORE     COUNT     MEASURE   ERROR      MNSQ   ZSTD   MNSQ   ZSTD |
|-----------------------------------------------------------------------------|
| MEAN     416.4     137.0         .00     .06        .99    -.1   1.11     .3 |
| S.D.      84.2        .0         .32     .00        .18    1.4    .55    1.7 |
| MAX.     537.0     137.0         .61     .07       1.41    3.2   2.56    4.2 |
| MIN.     261.0     137.0        -.47     .06        .76   -2.2    .54   -1.8 |
|-----------------------------------------------------------------------------|
| REAL RMSE    .06 TRUE SD     .31  SEPARATION  4.83  Item   RELIABILITY  .96 |
|MODEL RMSE    .06 TRUE SD     .31  SEPARATION  5.00  Item   RELIABILITY  .96 |
| S.E. OF Item MEAN = .07                                                     |
-------------------------------------------------------------------------------
```

Fig. 2: Summary statistics for item

Item STATISTICS: MEASURE ORDER

ENTRY NUMBER	TOTAL SCORE	TOTAL COUNT	MEASURE	MODEL S.E.	INFIT MNSQ	INFIT ZSTD	OUTFIT MNSQ	OUTFIT ZSTD	PT-MEASURE CORR.	PT-MEASURE EXP.	EXACT MATCH OBS%	EXACT MATCH EXP%	Item
18	261	137	.61	.07	.82	-1.4	.57	-1.2	.58	.52	47.7	47.1	4a
6	272	137	.56	.07	.80	-1.5	.54	-1.4	.60	.53	47.7	45.6	1c(ii)
3	301	137	.43	.06	1.04	.3	.77	-.7	.56	.56	42.3	41.1	1b(i)
16	315	137	.38	.06	1.01	.1	1.13	.6	.56	.57	37.7	38.2	3b(ii)
11	318	137	.37	.06	.91	-.7	.74	-.9	.61	.57	36.9	37.7	2d(ii)
17	334	137	.30	.06	.97	-.2	1.37	1.4	.59	.58	33.8	34.8	3c
2	346	137	.26	.06	.82	-1.6	.94	-.2	.59	.59	37.7	33.5	1a(ii)
5	347	137	.25	.06	.95	-.4	1.05	.3	.61	.59	33.1	33.4	1c(i)
7	405	137	.04	.06	.96	-.3	.97	.0	.61	.61	28.5	31.5	2a
1	411	137	.02	.06	.76	-2.2	.95	-.1	.62	.61	31.5	30.9	1a(i)
10	415	137	.01	.06	1.41	3.2	2.15	4.1	.49	.61	27.7	29.6	2d(i)
13	459	137	-.16	.06	1.26	2.1	2.39	4.2	.50	.61	26.9	31.8	3a(ii)
23	460	137	-.16	.06	.96	-.3	.91	-.3	.63	.61	32.3	31.8	4c(iv)
20	461	137	-.16	.06	.91	-.8	.93	-.2	.64	.61	31.5	31.9	4c(i)
21	467	137	-.19	.06	.77	-2.1	.62	-1.7	.68	.61	35.4	32.0	4c(ii)
22	478	137	-.23	.06	.80	-1.8	.57	-1.8	.68	.61	35.4	34.1	4c(iii)
15	481	137	-.24	.06	1.07	.7	1.05	.3	.60	.61	35.4	34.2	3b(i)
14	489	137	-.27	.06	1.21	1.7	1.20	.8	.57	.61	35.4	36.7	3a(iii)
4	490	137	-.28	.06	.96	-.3	.82	-.6	.64	.61	37.7	36.8	1b(ii)
19	498	137	-.31	.06	.92	-.6	.71	-1.0	.64	.61	42.3	38.8	4b
8	515	137	-.38	.06	1.26	2.0	2.56	3.7	.52	.61	40.8	42.3	2b
9	518	137	-.39	.07	1.01	.1	.97	.0	.60	.61	43.8	42.5	2c
12	537	137	-.47	.07	1.26	1.9	1.66	1.7	.54	.61	45.4	47.9	3a(i)
MEAN	416.4	137.0	.00	.06	.99	-.1	1.11	.3			36.8	36.7	
S.D.	84.2	.0	.32	.00	.18	1.4	.55	1.7			5.9	5.3	

Fig. 3: Item statistics

Table of STANDARDIZED RESIDUAL variance (in Eigenvalue units)

		-- Empirical --			Modeled
Total raw variance in observations	=	43.2	100.0%		100.0%
Raw variance explained by measures	=	20.2	**46.8%**		46.4%
Raw variance explained by persons	=	7.0	16.1%		16.0%
Raw Variance explained by items	=	13.3	30.7%		30.4%
Raw unexplained variance (total)	=	23.0	53.2%	100.0%	53.6%
Unexplned variance in 1st contrast	=	2.7	**6.4%**	11.9%	
Unexplned variance in 2nd contrast	=	2.1	4.9%	9.3%	
Unexplned variance in 3rd contrast	=	1.6	3.8%	7.2%	
Unexplned variance in 4th contrast	=	1.6	3.6%	6.8%	
Unexplned variance in 5th contrast	=	1.4	3.3%	6.3%	

Fig. 4: Item dimensionality

The groups are "high performers" and "low performers". The person mean is -0.02. This means that student's ability to answer the final exam is lesser than the expected performance. The negative mean also reflects that the students are less competent. The maximum of person on the difficulty logit is +2.44 and the minimum is -2.04.

Summary statistics for item: Figure 2 represents the measurement of items involved in this study. Items represent the questions tested on the final exam. The item reliability is 0.96. This indicates good item difficulty spread.

Item separation means the gap between the items of different levels of difficulty. A higher gap of separation indicates that there is a shortage of items. The item separation is 4.83. This means that the questions can be classified into four groups. They are "very difficult", "difficult", "easy" and "very easy". The item mean is 0. The maximum item on the logit ruler is 0.61 while the minimum item is -0.47.

Item statistics: Figure 3 shows the item statistics for the Engineering Mathematics I final exam. Rasch Model examined the item fit by infit and outfit (Draugalis and Jackson, 2004). A point-measure correlation calculates the index of the item discrimination where the item with greater value might be too good compared to other items (Othman *et al*., 2012). The point measure correlation value must be within $0.4<x<0.8$ (Aziz *et al*., 2008) all the 23 items are within this range. Next, the range for outfit mean square is $0.5<MNSQ<1.5$ (Linacre, 2005). All the items are within this range. Lastly, the range for outfit z-standard is $-2<z<2$ (Bond and Fox, 2007). All the items except item 2d

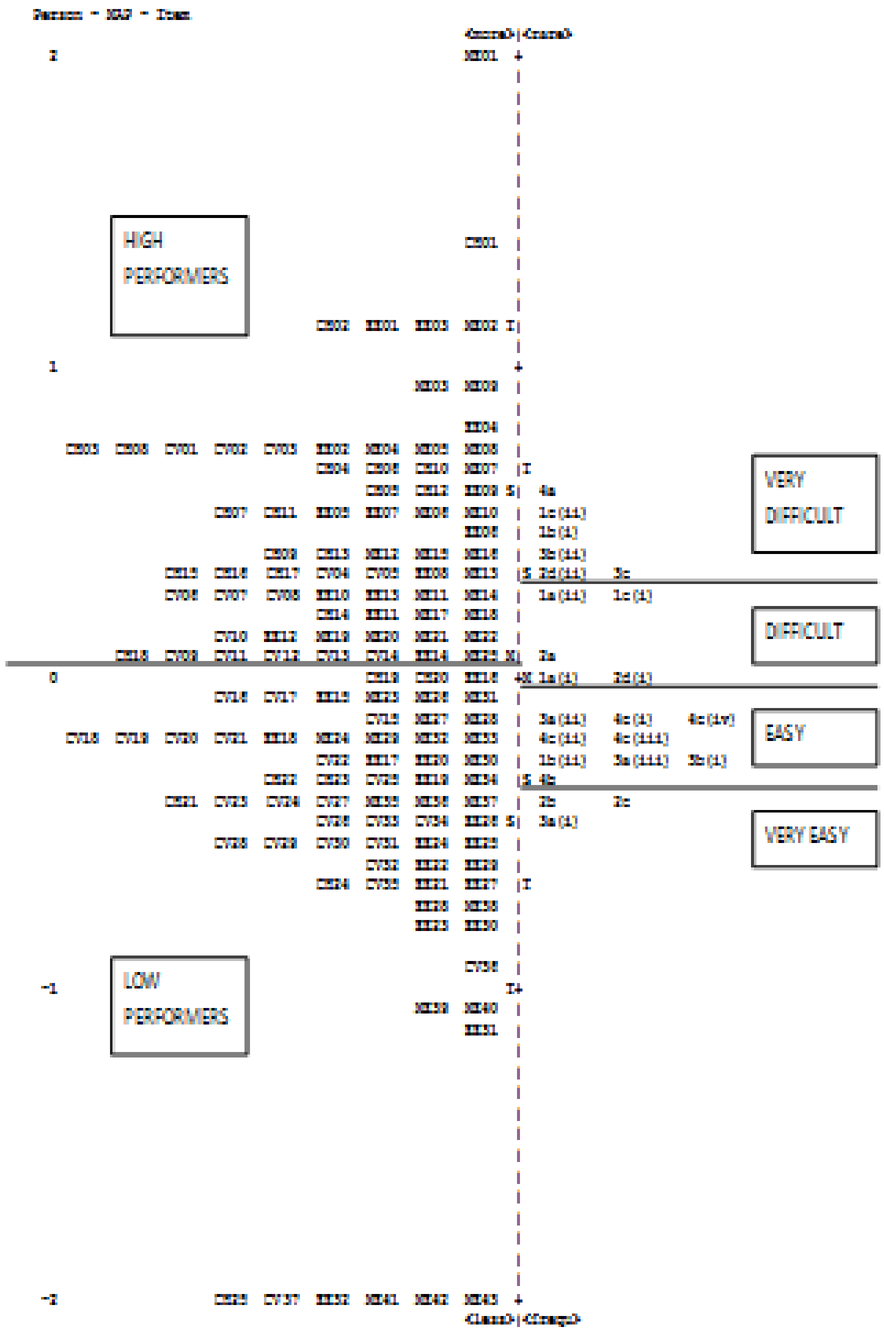

Fig. 5: Person-item distribution map

(i), 3a (iv) and 2 (b) are within the range. Since, item 2d (i), 3a (iv) and 2 (b) are only out of range for z-standard, thus, these items are not considered as misfit item. An item classifies as misfit item, if the item is out of range for point-measure correlation, outfit mean square and z-standard.

Item dimensionality: Figure 4 shows the item dimensionality for Engineering Mathematics I final exam. The unexplained variance (total) from Fig. 4 is 46.8%. Raw variance explained by measure >40% is accepted as an indicator of uni-dimensionality (Linacre, 2006). The unexplained variance in 1st contrast explains 6.4% of the variance. This value is within the acceptable range of 5-15%. Thus, the exam questions are uni-dimensional.

Person-item distribution map: Figure 5 represents the Person Item Distribution Map (PIDM) where Rasch Model provides the location of all the students on the vertical logit ruler, indicated by a dashed vertical line. As indicated, the higher the person was located on the map, the most competent the student. In contrast, the question is like the hurdle to the students. The lower a question on the ruler, the easier the question will be and vice versa. The scale for the items is made up samples ranging from 0.61 to -0.47 where the most difficult item and the most able exam takers were laid out on top of the scale. On the left side, each student was represented by their department number, for example, CH01 representing a student who took Engineering Mathematics I final from Chemical Engineering Department. The right-hand side illustrates the final exam questions which were represented by numbers. For example, 4a means the first part of question 4.

PIDM shows that the final exam questions for Engineering Mathematics I can be divided into 4 categories namely; very difficult, difficult, easy and very easy. Questions 4a, 1c, 1b, 3b, 2d and 3c are categorized in the very difficult group. Question 1b is a comprehension level of question. This question requires the students to define the formula of differentiation using the first principles. Question 1c, requires student to calculate the minimum perimeter. Question 2d needs to be solved using the inverse matrix approach. Question 3b (ii) requires the student to find the unit vector parallel with another vector. Both question 3c and 4a is the analysis level. Question 3c requires to find the area of a triangle in space whereas question 4a needs a student to solve the square root of complex number.

Question 1a (ii), 1c (i), 2a, 1a (i) and 2d (i) are categorized in the difficult group. Question 1a (i) and 1a (ii) are the application level of questions. These questions need to be solved using the product rule and quotient rule of differentiation. Question 1c (i) is comprehension level. This question needs to prove the perimeter of the diagram as given. Question 2a is knowledge level in Bloom taxonomy. Students should state three methods for solving the system of linear equations. Lastly, question 2d (i) which falls under comprehension category requires students to write a system of linear equation in the matrix form based on the information given. The easy group questions are 3a (ii), 4c (i), 4c (iv), 4c (ii), 4c (iii), 1b (ii), 3a (iii), 3b (i) and 4 (b). Sketching graph for function, simplify complex number, subtraction of vector and polar form of complex number are the easy topics for the students. Questions 2b, 2c and question 3a (i) belong to the very easy group. Finding determinant for a 3×3 matrix, solving equations using Cramer's rule and stating the domain of a function are the easiest topics in the Engineering Mathematics I subject.

The students can be divided into two groups, namely high performers and low performers. The students who are above the mean line are considered high performers and those who are below the mean line are low performers. There is a balance of high and low performers in Engineering Mathematics I subject. Table 7 summarizes the results of the person-item distribution map.

Table 7: Summary of PIDM

Questions	Bloom taxonomy	Course Outcome (CO)	Categories
1a (i)	Application	1	Difficult
1a (ii)	Application	1	Difficult
1b (i)	Comprehension	1	Very difficult
1b (ii)	Application	1	Easy
1c (i)	Comprehension	1	Difficult
1c (ii)	Application	1	Very difficult
2a	Knowledge	2	Difficult
2b	Application	2	Very easy
2c	Application	2	Very easy
2d (i)	Comprehension	2	Difficult
2d (ii)	Application	2	Very difficult
3a (i)	Knowledge	3	Very easy
3a (ii)	Knowledge	3	Easy
3a (iii)	Application	3	Easy
3b (i)	Application	3	Easy
3b (ii)	Application	3	Very difficult
3c	Analysis	3	Very difficult
4a	Analysis	4	Very difficult
4b	Application	4	Easy
4c (i)	Application	4	Easy
4c (ii)	Application	4	Easy
4c (iii)	Application	4	Easy
4c (iv)	Application	4	Easy

Engineering Mathematics II summary statistics for person: The summary of the statistical results for the measurement of person is given in Fig. 1. Person represents the students who sat for the Engineering Mathematics II final exam. The Cronbach alpha shows that the test reliability is 0.97. The person reliability is 0.80.

Figure 6, the person separation is 2.03 logit. Therefore, the students can be divided into three groups. The groups are "high performers", "medium performers" and "low performers". The person mean is -0.02. This means that student's ability to answer the final exam is lesser than the expected performance. The negative mean also reflects that the students are less competent. The maximum of person on the difficulty logit is +1.95 and the minimum is -0.86.

SUMMARY OF 34 MEASURED Person

	TOTAL SCORE	COUNT	MEASURE	MODEL ERROR	INFIT MNSQ	INFIT ZSTD	OUTFIT MNSQ	OUTFIT ZSTD
MEAN	46.2	15.0	.03	.22	.96	-.1	1.30	.2
S.D.	13.4	.0	.58	.10	.46	1.1	1.42	1.1
MAX.	74.0	15.0	1.95	.78	2.07	2.5	4.98	3.1
MIN.	23.0	15.0	-.86	.18	.44	-2.0	.31	-1.1

REAL RMSE .25 TRUE SD .52 SEPARATION 2.03 Person RELIABILITY .80
MODEL RMSE .24 TRUE SD .52 SEPARATION 2.18 Person RELIABILITY .83
S.E. OF Person MEAN = .10

Person RAW SCORE-TO-MEASURE CORRELATION = .97
CRONBACH ALPHA (KR-20) Person RAW SCORE "TEST" RELIABILITY = .83

Fig. 6: Summary statistics for person

SUMMARY OF 15 MEASURED Item

	TOTAL SCORE	COUNT	MEASURE	MODEL ERROR	INFIT MNSQ	INFIT ZSTD	OUTFIT MNSQ	OUTFIT ZSTD
MEAN	104.8	34.0	.00	.14	.99	-.1	1.30	.3
S.D.	33.3	.0	.55	.03	.23	.8	.91	1.2
MAX.	152.0	34.0	1.11	.21	1.53	1.2	3.52	3.3
MIN.	46.0	34.0	-.81	.11	.63	-1.4	.41	-1.1

REAL RMSE .15 TRUE SD .53 SEPARATION 3.55 Item RELIABILITY .93
MODEL RMSE .14 TRUE SD .53 SEPARATION 3.78 Item RELIABILITY .93
S.E. OF Item MEAN = .15

Fig. 7: Summary statistics for item

Item STATISTICS: MEASURE ORDER

ENTRY NUMBER	TOTAL SCORE	TOTAL COUNT	MEASURE	MODEL S.E.	INFIT MNSQ	INFIT ZSTD	OUTFIT MNSQ	OUTFIT ZSTD	PT-MEASURE CORR.	PT-MEASURE EXP.	EXACT MATCH OBS%	EXACT MATCH EXP%	Item
8	46	34	1.11	.21	1.21	.5	2.11	1.1	.48	.55	82.4	81.5	3a
7	50	34	.96	.18	1.53	1.2	2.49	1.3	.40	.56	73.5	75.3	2b
2	68	34	.52	.14	1.10	.4	2.37	1.7	.54	.60	41.2	45.9	1a(ii)
12	75	34	.40	.13	.78	-.8	.54	-.8	.68	.60	38.2	33.5	3c
13	88	34	.21	.12	1.15	.8	1.53	1.1	.54	.59	29.4	32.0	4a(i)
14	93	34	.14	.12	1.01	.1	1.00	.1	.59	.58	29.4	30.1	4a(ii)
6	103	34	.01	.11	1.19	1.0	1.70	1.5	.49	.57	26.5	31.7	2a(iv)
11	106	34	-.03	.11	.80	-1.1	.61	-.9	.65	.57	32.4	32.0	3b(iii)
4	109	34	-.07	.12	.74	-1.4	.56	-1.1	.66	.56	38.2	29.9	2a(ii)
10	125	34	-.30	.12	.95	-.1	3.52	3.3	.27	.53	17.6	31.6	3b(ii)
1	136	34	-.47	.13	.91	-.2	.60	-.6	.58	.49	35.3	36.9	1a(i)
3	137	34	-.49	.13	.63	-1.4	.41	-1.1	.65	.48	32.4	37.3	2a(i)
5	138	34	-.51	.13	1.16	.6	.88	.0	.41	.48	32.4	39.3	2a(iii)
15	146	34	-.67	.15	.89	-.3	.58	-.5	.50	.43	52.9	52.5	4b
9	152	34	-.81	.16	.80	-.5	.61	-.3	.44	.38	61.8	64.3	3b(i)
MEAN	104.8	34.0	.00	.14	.99	-.1	1.30	.3			41.6	43.6	
S.D.	33.3	.0	.55	.03	.23	.8	.91	1.2			17.6	16.5	

Fig. 8: Item statistics

Summary statistics for item: Figure 7 represents the measurement of items involved in this study. Items represent the questions tested on the final exam. The item reliability is 0.93. This indicates good item difficulty spread.

Item separation means the gap between the items of different levels of difficulty. A higher gap of separation indicates that there is a shortage of items. The item separation is 3.55. This means that the questions can be classified into four groups. They are "very difficult",

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Table of STANDARDIZED RESIDUAL variance (in Eigenvalue units)
                                            -- Empirical --    Modeled
Total raw variance in observations     =         33.2 100.0%        100.0%
  Raw variance explained by measures   =         18.2  54.9%         53.2%
    Raw variance explained by persons  =          6.1  18.3%         17.8%
    Raw Variance explained by items    =         12.1  36.5%         35.4%
  Raw unexplained variance (total)     =         15.0  45.1% 100.0%  46.8%
    Unexplned variance in 1st contrast =          2.6   7.7%  17.1%
    Unexplned variance in 2nd contrast =          2.0   6.1%  13.5%
    Unexplned variance in 3rd contrast =          1.7   5.1%  11.3%
    Unexplned variance in 4th contrast =          1.6   4.7%  10.4%
    Unexplned variance in 5th contrast =          1.4   4.2%   9.2%
```

Fig. 9: Item dimensionality

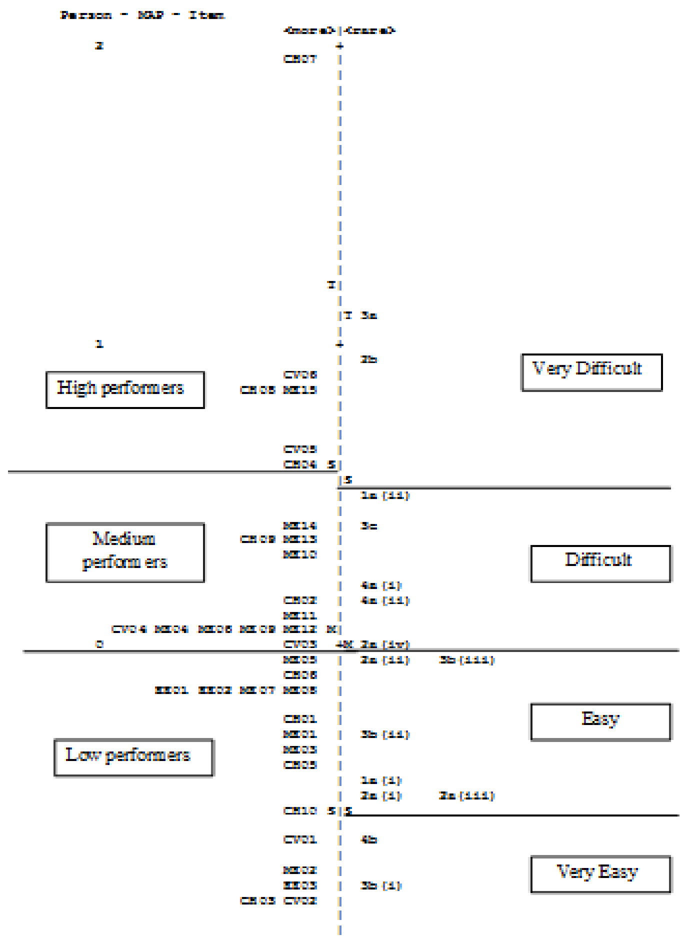

Fig. 10: Person-item distribution map

"difficult", "easy" and "very easy". The item mean is 0. The maximum item on the logit ruler is 1.11 while the minimum item is -0.81.

Item statistics: Figure 8 shows the item statistics for the Engineering Mathematics II final exam. Rasch Model examined the item fit by infit and outfit (Draugalis and Jackson, 2004). A point-measure correlation calculates the index of the item discrimination where the item with greater value might be too good compared to other items (Othman *et al*., 2012). The point measure correlation value must be within (Aziz *et al*., 2008). All the 15 items are within this range. Next, the range for outfit mean square is (Linacre, 2005). Item 3 (a), 2 (b), 1a (ii), 4a (i), 2a (iv), 3b (ii) and 2a (i) are out of the range. Lastly, the range for outfit z-standard is (Bond and Fox, 2007). All the items except item 3b (ii) are within the range. No items are considered as misfit item for Engineering Mathematics II final exam.

Item dimensionality: Figure 9 shows the item dimensionality for Engineering Mathematics II final exam. The unexplained variance (total) from Fig. 4 is 54.9%. Raw variance explained by measure >40% is accepted as an indicator of uni-dimensionality (Linacre, 2006) (Fig. 10). The unexplained variance in 1st contrast explains 7.7% of the variance. This value is within the acceptable range of 5-15%. Thus, the exam questions are uni-dimensional.

Person-item distribution map: Figure 10 refers to the Person Item Distribution Map (PIDM) for Engineering Mathematics II. The discussion aims at the performance of the item with all of the 15 items spread on the logit scale. The scale for the items is made up samples ranging from 1.11 to -0.81 where the most difficult item and the most able exam takers were laid out on top of the scale. On the left side, each student was represented by their department number, for example, CH07 representing a student who took Engineering Mathematics II final from Chemical Engineering Department. The right-hand side illustrates the test item which was represented by numbers. For example, 3a means the first part of question 3.

PIDM shows that the final test questions can be divided into four categories, namely very difficult, difficult, easy and very easy.

Questions 2b and 3a are categorized in the very difficult group. Question 2b is an analysis level of question. This question requires students to analyze and then solve the given problem using integration of exponential function. Question 3a is an application level of question. This question requires the students to solve first order differential equation.

Question 1a (ii), 2a (iv), 3c, 4a (i) and 4a (ii) are categorized in the difficult group. Question 1a (ii), 3c and 4a (i) are the comprehension level of questions. Question 1a(ii) required to give conclusion from the results. Question 3c required students to solve first order Laplace transform. Question 4a (i) is sketching graph for a function. Question 2a (iv) and question 4a (ii) are application questions. Questions 2a (iv) required to solve question using integration by substitution where else question 4a (ii) is solving Fourier series question.

The easy group questions are 1a (I), 2a (i), 2a (ii), 2a (iii), 3b (ii) and 3b (iii). Partial differentiation, integration by substitution, integration of partial fraction, integration of exponential function, integration of trigonometric function and Laplace function are the easy topics for the students. Question 3b (i) and 4b belong to the very easy group. Laplace function and Maclaurin series are the easiest topics in the Engineering Mathematics II subject. Both are knowledge level of questions. Table 8 summarizes the results of the person-item distribution map. Differentiation using first principle, differentiate functions, finding minimum functions, solving system of linear equations using inverse matrix, finding unit vector and finding the root of complex numbers are the challenging topics in Engineering Mathematics I.

Generally, integration of exponential function, integration by substitution, first order differential equation, solving the first order differential equation using Laplace transform, sketch graph and Fourier series are the challenging topics in Engineering Mathematics II. Table 9 summarizes the challenging topics in a particular course outcome for Engineering Mathematics I and II subjects.

Table 8: Summary of PIDM

Questions	Bloom taxonomy	Course Outcome (CO)	Categories
1a (i)	Analysis	1	Easy
1a (ii)	Comprehension	1	Difficult
2a (i)	Application	2	Easy
2a (ii)	Application	2	Easy
2a (iii)	Application	2	Easy
2a (iv)	Application	2	Difficult
2b	Analysis	2	Very difficult
3a	Application	3	Very difficult
3b (i)	Knowledge	3	Very easy
3b (ii)	Knowledge	3	Easy
3b (iii)	Knowledge	3	Easy
3c	Comprehension	3	Difficult
4a (i)	Comprehension	4	Difficult
4a (ii)	Application	4	Difficult
4b	Knowledge	4	Very easy

Table 9: Challenging topics in Engineering Mathematics

Subjects/Course outcomes	Challenging topics
Engineering Mathematics I	
Apply polar form in De Moivre's Theorem and roots of complex numbers	Finding the root of complex numbers
Solve matrix algebra including linear system of equations, eigenvalues and eigenvectors	Solving a system of linear equations using inverse matrix
Solve differentiation and its application in vectors	Differentiation using first principle, differentiate functions, finding minimum functions, finding unit vector
Engineering Mathematics II	
Solve integration problems by various methods	Integration of exponential function, integration by substitution
Apply Calculus in Maclaurin, Taylor and Fourier series	Sketch graph and Fourier series
Solve differential equations, Laplace transform and inverse Laplace transform	First order differential equation, using Laplace transform to solve first order differential equation

CONCLUSION

The study concluded that the final exam questions for Engineering Mathematics I and II are well designed and constructed. Apply polar form in De Moivre's theorem and roots of complex numbers, solve matrix algebra including a linear system of equations, eigenvalues and eigenvectors, solve differentiation and its application in vectors are the challenging course outcomes identified from the Engineering Mathematics I final exam questions.

Solve integration problems by various methods, apply Calculus in Maclaurin, Taylor and Fourier series, solve differential equations, Laplace transforms and inverse Laplace transform are the challenging course outcomes identified from the Engineering Mathematics II final exam questions.

In the coming semester, the lecturer must spend more time stressing on the challenging topics and giving more questions to try during class. Then students should have a paired discussion with their friends. Lastly, the lecturers can give the answers and if still any students are not clear about the answers, the lecturers should give further explanation.

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