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Evaluating Performance of Students in Engineering Statistics Final Exam Questions

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***Abstract*---**Engineering Statistics is one of Engineering Mathematics subject which is common for all the engineering courses besides Vector Calculus, Linear Algebra, Differential Equations and Numerical Analysis. Students performance in Engineering Statistics subject can be evaluated examining through the final exam questions. Students need to understand the concept learn through a semester or 14 weeks of period and do necessary preparation to do the final exam questions. Rasch model is used to evaluate students performance in Engineering Statistics examination. A total of 114 engineering students sat for Engineering Statistics final examination. There are 5 Course Outcomes and 2 Programme Outcomes for Engineering Statistics subject. The final exam marks were entered in excel. Then the marks transferred to *prn format. Next Rasch model generate the output. The outputs are summary statistics for person, summary statistics for item, item map and person map. The summary statistics for person able to groups the students into 2 groups, namely high performers and low performers. On the other hand, the items can be group into 4 groups. They are difficult, mediocre, easy and very easy. The item map and the person map able to show those groups clearly. Rasch model able to identify the level of difficulties of each Course Outcome from Business Statistics subject.

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Introduction

Engineering Mathematics is a common subjects for all the engineering courese nationally or internatuionally. Thus a strong foundation in Engineering Mathematics will ensure the students performance in the main engineering subjects. This is the reason that the Engineering Mathematics subjects are introduced from the first year and beginning from semester 1 onwards. Vector Calculus, Linear Algebra, Differential Equations, Engineering Statistics and Numerical Analysis are the Engineering Mathematics subjects offered to engineering students.

Students performance in Engineering Statistics subject can be evaluated based on their performance in the final examinations. The Rasch model can give a detail description on how well the students answered the final exam questions. This also includes on identifying the easiest topic and the difficult topic in Engineering Statistics. Lecturers who areteaching in the upcoming semester can use this results as a guideline on setting the final examination questions. Lecturers also can give more examples and more information on the difficult topics so that students will understand in depth of the topics.

Dichotomous Rasch model is a situation whereby the score for each item is either 0 or 1 or the answer for any question is yes or no [1]. Reference [2] used dichotomous Rasch model in a research on 20 items for 74 students in a Statistics and Probability subject. The results showed that 83% of the students have the same ability with the difficulty of questions and 17% of the students should be given attention and help on the topics. Rasch model was used extensively to examine the reliability of exam questions and the impact on students [3], [4], [5], [6] and [7]. Students performance not only depends on the ability to answer the exam questions but also depends on the relevancy of the questions.

Rasch model is proved to be an effective tool in examine the quality of final exam questions with accurate although small sample is used [8]. Examination questions need to arranged from the easiest to the difficult so that students have more time in answering the difficult questions [9]. Questions also can be arranged from the chronological order of course outcome and then from the easiest to the most difficult. This will ensure the course outcome is covered and the depth of knowledge of the subject has been examined.

Methodology

The final examination for Engineering Statistics was conducted in session 2017 / 2018. After the students undergo a teaching of 14 weeks in a semester, the final exam was conducted. The total percentage of the mid semester test, assignment, quiz and final examination will determines the grade of a student for the Engineering Statistics subject. A total of 7 subjective questions were designed and validated by a group of lecturers. The duration of the final examination is 3 hours and the total marks are 100. A total of 114 students from Mechanical Engineering department sat for the final exam of Engineering Statistics.

Table 1 list the Course Outcome for Business Statistics subject. There are a total of 5 Course Outcomes. They are understand basic concepts of probability distributions, able to perform appropriate hypothesis testing, able to perform simple linear regression and correlation analysis, able to use different tools in quality control and able to solve and interpret engineering problems using appropriate statistical methods.

Table 2 shows the Programme Outcome for Business Statistics subject. There are a total of 12 Programme Outcome. These Programme Outcome are the same for any engineering subject. This also includes Business Statistics and other Engineering Mathematics subjects. The Programme Outcomes are engineering knowledge, problem analysis, design/development of solution, investigation, modern tool usage, the engineer and society, environment and sustainability, ethics, communication, individual and team work, lifelong learning and project management and finance.

Table 3 illustrates the distribution of final exam questions together with the distribution of marks for each of the question. Table 4 shows the details entry of each of the final exam questions. This includes the details of Course Outcome, Programme Outcome, the level of Bloom Taxonomy and the description of Bloom Taxonomy for each question.

Table 1
Course outcome for business statistics subject

Course Outcome	Description
1	Understand basic concepts of probability distributions.
2	Able to perform appropriate hypothesis testing.
3	Able to perform simple linear regression and correlation analysis.
4	Able to use different tools in quality control.
5	Able to solve and interpret engineering problems using appropriate statistical methods.

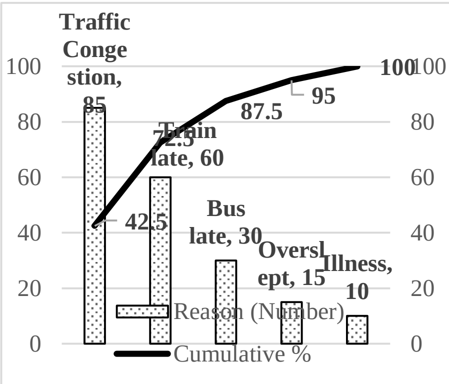
Table 2
Programme outcome for business statistics subject

Programme Outcome	Description
1	Engineering knowledge
2	Problem analysis
3	Design / development of solutions

Programme Outcome	Description
4	Investigation
5	Modern tool usage
6	The engineer and society
7	Environment and sustainability
8	Ethics
9	Communication
10	Individual and team work
11	Lifelong learning
12	Project management and finance

Table 3
Final exam questions

Q	Description	Marks
1(a)	In an industrial process the diameter of a ball bearing is an important component. The buyer sets specification on the diameter to be 3.0 ± 0.01 cm. The implication is that no part falling outside these specifications will be accepted. It is known that in the process, the diameter of a ball bearing has a normal distribution with mean 3.0 and standard deviation 0.005. On the average, how many manufactured ball bearings will be scrapped?	5
1(b)	Gauges are used to reject all components where a certain dimension is not within the specification of 1.50 ± *e*. It is known that this measurement is normally distributed with mean 1.50 and standard deviation 0.2. Determine *e* such that the specification cover 95% of the measurements.	5
2(a)	What is the difference between sample and population?	2
2(b)	A principal at a certain school claims that the students in his school are above average intelligence. A random sample of thirty students IQ scores have a mean score of 112. Is there sufficient evidence to support the principal's claim? The mean population IQ is 100 with a variance of 225. IQ scores are normally distributed. (Use a significance level of $\alpha = 0.05$)	8
3	The sodium content (in milligrams) of twenty five boxes of organic cornflakes was determined. The data are as follows: 131.15 130.69 130.91 129.54 129.64 128.77 128.77 128.33 128.24 129.65 130.14 129.29 128.71 129.00 129.39 130.42 129.53 130.12 129.78 130.92 130.80 129.73 133.15 128.77 129.74 Construct a two-sided confidence interval on the mean	10

Q	Description	Marks
	sodium content. Can you support the claim that mean sodium of this brand of cornflakes differs from 130 mg? Use α = 0.05.	
4	In a survey to find the main causes of lateness in a factory's work force, a random sample of 200 employees who were late for work were asked the reason why. The Pareto in Fig. 1 shows the results.  Fig. 1 Pareto Chart for main causes of lateness in a factory's work Based on Pareto chart in Fig. 1, make a simple report of the main causes to account for 90% of the problem. In your report includesall the statistical information from Figure 1.	10
5	As part of an industrial training program, some trainess are instructed by Method A, which is straight computer-based instruction, and some are instructed by Method B, which also involves the personal attention of an instructor, Ifrandom samples of size 10 are taken from large group of trainees instructed by each of these two methods, and the scores which they obtained in an appropriate achievements test as follow. Method A 71 75 65 69 73 66 68 71 74 68 Method B 72 77 84 78 69 70 77 73 65 75 Use the 0.05 level of significance to test the claim that Method B is more effective. Assume that the population sampled can be approximated closely with normal distribution having the same variance.	20
6	A research foundation studied the deflection (mm) of particleboard fromm stresslevels of relative humidity. Assume that these two variables (stress level and deflection) are both related according to the simple linear regression model. The data are shown below:	

Q	Description	Marks
	x = Stress level (%) y = Deflection (mm) x 54, 54, 61, 61, 68, 68, 75, 75, 75 y 16.473, 18.693, 14.305, 15.121, 13.505, 11.168, 12.534, 11.224	
6(a)	Calculate the least square estimates of the slope and intercept.	8
6(b)	Find the estimate of the mean deflection if the stress level can be limited to 64%.	3
6(c)	Estimate the change in the mean deflection associated with 5% increment in stress level.	2
6(d)	At 5% significant level, develop hypothesis for stress level coefficient (use σ^2= 1.07)	7
7	The copper content of a planning bath is measured three times per day, and the results are reported in parts per million (ppm). The $\bar{x}$ and r values for 25 days are shown in the following table	

Day	$\bar{x}$	r	Day	$\bar{x}$	r
1	6.3	1.2	14	7.0	1.4
2	5.4	0.8	15	5.8	1.4
3	6.8	1.4	16	6.4	1.0
4	6.7	1.2	17	6.3	0.8
5	5.8	1.4	18	6.4	1.4
6	7.2	0.8	19	7.0	1.0
7	6.4	1.0	20	6.4	1.2
8	6.5	1.2	21	6.5	0.8
9	7.2	1.4	22	6.4	1.2
10	6.3	1.0	23	6.3	0.8
11	6.4	0.8	24	6.4	1.2
12	5.4	1.4	25	6.3	1.2
13	6.3	0.8			

Q	Description	Marks
7(a)	Using all the data, draw the trial control limits on $\bar{X}$ and R charts, and conclude your findings.	12
7(b)	If necessary, revise the control limits computed in part (a), assuming that any samples that plot outside the control limits can be eliminated. (DO NOT PLOT THE CHART)	8

Table 4
Entry number for final questions

Q	Course Outcome	Programme Outcome	Bloom Taxonomy Level	Description
1(a)	CO1	PO1	3	Application
1(b)	CO1	PO1	4	Application
2(a)	CO2	PO2	2	Understand
2(b)	CO2	PO2	5	Synthesis

Q	Course Outcome	Programme Outcome	Bloom Taxonomy Level	Description
3	CO2	PO2	5	Synthesis
4	CO5	PO2	6	Evaluation
5	CO2	PO2	5	Synthesis
6(a)	CO3	PO2	3	Application
6(b)	CO3	PO2	3	Application
6(c)	CO3	PO2	3	Application
6(d)	CO3	PO2	5	Synthesis
7(a)	CO4	PO2	3	Application
7(b)	CO4	PO2	4	Analysis

Results and Discussion

As a first step, grades were compiled in the EXCEL *prn format. The grades were transferred using Bond and Fox [10] known as WINSTEPS. It is a Rasch analysis software used to obtain the logit values. Figure 1 shows the summary statistics for person. Person represents the students who took Business Statistics final examination. The person summary reveals a strong reliability of Cronbach Alpha = 0.78 and person reliability = 0.67. The result of separation was 1.42 indicating that the students can be divided into two groups.

Figure 2 shows the summary statistics for the 13 items involved in this study. “Items” represents the questions tested on the final examination. The item summary summarises very high reliability of 0.97 and item separation = 5.74. The value of the item separation indicates that the final exam questions can be grouped into five groups. The value for the mean item is 0.

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SUMMARY OF 114 MEASURED (EXTREME AND NON-EXTREME) Person
-------------------------------------------------------------------------------
|          TOTAL                         MODEL         INFIT        OUTFIT    |
|          SCORE     COUNT     MEASURE    S.E.      MNSQ   ZSTD   MNSQ   ZSTD |
|-----------------------------------------------------------------------------|
| MEAN      47.2      13.0         .42     .26                                |
|  SEM       1.0        .0         .05     .02                                |
| P.SD      10.1        .0         .58     .19                                |
| S.SD      10.2        .0         .59     .19                                |
| MAX.      65.0      13.0        2.68    1.57                                |
| MIN.      25.0      13.0        -.60     .20                                |
|-----------------------------------------------------------------------------|
| REAL RMSE    .34 TRUE SD     .48  SEPARATION  1.42  Person RELIABILITY  .67 |
|MODEL RMSE    .32 TRUE SD     .49  SEPARATION  1.51  Person RELIABILITY  .69 |
| S.E. OF Person MEAN = .05                                                   |
-------------------------------------------------------------------------------
Person RAW SCORE-TO-MEASURE CORRELATION = .94
CRONBACH ALPHA (KR-20) Person RAW SCORE "TEST" RELIABILITY = .78  SEM = 4.80
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Figure 1. Summary statistics for person

SUMMARY OF 13 MEASURED (NON-EXTREME) Item

	TOTAL SCORE	COUNT	MEASURE	MODEL S.E.	INFIT MNSQ	INFIT ZSTD	OUTFIT MNSQ	OUTFIT ZSTD
MEAN	414.2	114.0	.00	.08	1.01	-.05	1.04	.11
SEM	26.9	.0	.15	.01	.06	.45	.08	.34
P.SD	93.0	.0	.50	.02	.20	1.56	.29	1.17
S.SD	96.8	.0	.52	.02	.21	1.62	.30	1.21
MAX.	542.0	114.0	.83	.13	1.26	2.02	1.69	2.25
MIN.	250.0	114.0	-.89	.07	.70	-2.64	.70	-1.92

REAL RMSE .09 TRUE SD .50 SEPARATION 5.74 Item RELIABILITY .97
MODEL RMSE .08 TRUE SD .50 SEPARATION 6.04 Item RELIABILITY .97
S.E. OF Item MEAN = .15

Figure 2. Summary statistics for item

Person problem-solving skills and item difficulty were mapped side by side on the same vertical line with the logit unit. Figure 3 refers to the Person-Item Distribution Map (PIDM). The discussion aims at the performance of the item with all of the 13 items spread on the logit scale. The scale for the items is made up samples ranging from -1 to 2 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 number for example 1 representing a student who took Business Statistics final examination from Mechanical Engineering Department. The right hand side illustrates the test item which was represented by numbers.

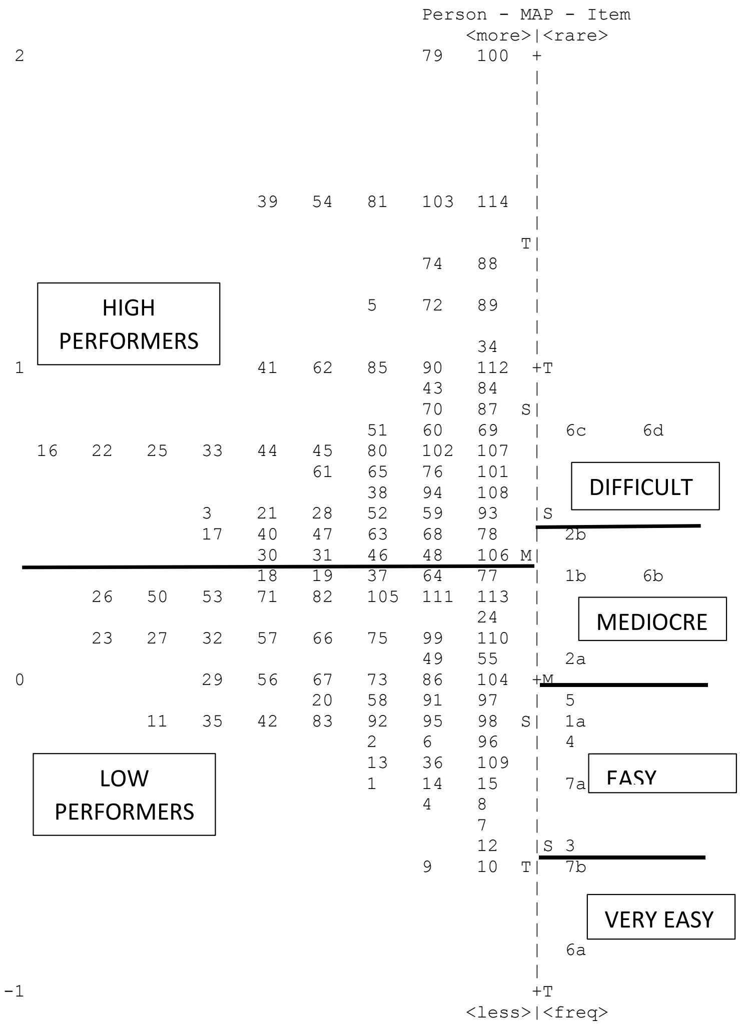

Figure 3. Person item distribution map

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