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Filtering the course outcomes for engineering mathematics lab via Rasch model

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ABSTRACT

The aim of this study is to use Rasch model as a method to filter the suitable course outcomes for Engineering Mathematics lab. A pre-test was conducted for each of the Vector Calculus, Linear Algebra and Differential Equation subjects. The analysis of each subject was run against the Rasch model. The person item distribution map managed to divide the course outcomes into different categories. The categories are very difficult, difficult, moderate and easy. From a total of 16-course outcomes from 3 subjects, only 8-course outcomes were filtered and chosen for the suggested Engineering Mathematics lab session. Partial derivatives, line integrals, Greens' theorem, vector space, power series, first and second order of differential equations, second order non-homogeneous differential equations and Fourier series are identified as the course outcomes for the lab sessions. A two-hour lab session is suggested for each of the course outcomes. Conducting lab sessions for Engineering Mathematics subjects parallel with traditional lectures will help the students widen their knowledge in Engineering Mathematics and to perform better in the subjects.

1. Introduction

Engineering Mathematics is recognized as a pre-requisite course for all the engineering courses. A good foundation in Engineering Mathematics will help students to perform well in their engineering courses. Yet, the poor problem-solving skills among students lead to under-achievement in Engineering Mathematics subjects. The decline in mathematics skills has been proven in several studies. Poor level of mathematics achievement among the first-year students enrolling in the engineering course is a cause for concern to the engineering faculty (Nopiah et al., 2015). Students' achievement in their pre-university level does not influence their achievement in the university. The study reveals that there are two groups of student need to be given special attention. They are the students from matriculation background and students from diploma background. During pre-university, students are exposed to basic knowledge of certain topic of mathematics but at the university level they need to understand theories of mathematics prior to the applications. At university level students study in-depth of any mathematics topics. Underachievement in mathematics courses resulted with the average passing rate below 70% for four consecutive years was reported (Tang et al., 2008). These 'high-failure' rate courses had a significant element of Pre-calculus and Basic calculus. Findings showed that students faced problems in understanding Calculus concepts. SPM Additional Mathematics, an exam equivalent with O level, taken by students in Malaysia was found as a good indicator for 'high-failure' rate subjects. In future students with strong grade in Additional mathematics should be recommended for Science-based programs.

In another study, which consists of 1050 full-time students from a public university in Sarawak, Malaysia, Pre-Calculus, Calculus I, Mathematics II and Engineering Mathematics I are grouped as underachievement mathematics courses (Tang et al., 2010). A failure rate of 21.5% up to 39.2% had been recorded in a first-year introductory Calculus course in a Norwegian University of Science and Technology (Gynnild et al., 2005). Evidence shown that mathematics performance of students in secondary

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school related to the performance of basic Calculus course in university. The study approach, less effort and lacking of skills in the math are the factors for poor performance. This is classified as 'students' responsibility towards learning.

Another study indicated that students' underachievement in Mathematics can be improved by seeking help from the university's mathematics learning support centre (Lee et al., 2008).

Recently, several local as well as international researchers have conducted some pre-tests. A study was conducted on predicting university performance for first-year engineering and science students in Australia (Barry and Chapman, 2007). Their finding reveals that a diagnostic test can be used to find a predictor formula for university admission to mathematical-based course.

In constructing the pre-test question, the level of Bloom Taxanomy must be included. A balanced task should comprise the same level of cognitive thinking skills to the student which reflects what they have studied (Ghulman and Masodi, 2009). These tasks should take into account Bloom's cognitive thinking skills to incorporate students' ability which reflects on students' performance.

2. Methodology

Engineering students from the Faculty of Engineering and Built Environment from Universiti Kebangsaan Malaysia have three common Engineering Mathematics subjects during their undergraduate course. Vector Calculus (KKKQ 1123) is offered in the first semester, Linear Algebra (KKKQ 1223) offered in the second semester and Differential Equation (KKKQ 2123) offered in the third semester.

A pre-test for Vector Calculus and Differential Equations were conducted in semester I 2015 / 2016. Another pre-test was conducted in semester II 2015 / 2016 for Linear Algebra. Each test was given 2 hours. All the pre-test were conducted as subjective questions. Each of the pre-test questions was validated by two internal lecturers who teach that respective subject.

All the pre-test questions were set up using Course Outcome and Programme Outcome as guideline. The pre-test questions were also constructed with the Bloom Taxonomy level (Knowledge, Comprehension, Application, analysis, Evaluation and Creation). Table 1 shows the course outcome for Vector Calculus. Table 2 shows the course outcome for Linear Algebra. Table 3 shows the course outcome for Differential Equation. Table 4 shows the programme outcome for engineering courses.

Table 5 shows the details of pre-final questions for Vector Calculus pre-test together with COs, POs and the level of Bloom's Taxonomy.

Table 1: Course outcome for vector calculus subject

CO	Description
1	Understand the basic of surfaces in space.
2	Able to apply the basic concepts of partial derivatives.
3	Understand and able to apply the concepts of vector function, vector field, scalar field, gradient, divergence and curl.
4	Able to apply the concepts of line integral, double integral and triple integral in solving engineering problems.
5	Able to apply Green's Theorem, Stokes' Theorem and Gauss Theorem in solving engineering problems.
6	Understand the basic concepts of differentiation and integration of complex functions.

Table 2: Course outcome for linear algebra subject

CO	Description
1	Understand the fundamental concepts on the matrix and its basic operations and applications.
2	Able to use the concepts of vector space, linear independent in the space dimension transformation.
3	Able to apply the eigenvector and eigenvalue in engineering problems.
4	Able to use the diagonalization and quadratic forms in the matrix solution for engineering problems
5	Able to understand the concepts of power series.

Table 3: Course outcome for differential equation subject

CO	Description
1	Understand the basic concepts of differential equations and their solutions.
2	Able to solve first and second order of differential equations.
3	Able to perform step-by-step analysis to model the simple engineering problem using differential equations and to solve the differential equations using an appropriate technique.
4	Able to evaluate the Laplace transform for solving ordinary differential equations.
5	Able to use Fourier series to solve partial differential equations.

Table 4: Programme outcome for vector calculus subject

PO	Description
1	Engineering knowledge
2	Problem analysis
3	Design / development of solutions
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 6 shows the details of pre-final questions for Linear Algebra pre-test together with COs, POs and the level of Bloom's Taxonomy. Table 7 shows the details of pre-final questions for Differential Equation pre-test together with COs, POs and the level of Bloom's Taxonomy.

3. Results and discussion

The marks are compiled in the Excel *prn format. Then the grades were transferred to WINSTEPS. The analysis of WINSTEPS (Linacre, 2008) is done against the Rasch model.

Table 5: Entry number for each question for vector calculus pre-test

Question	CO	PO	Level of Bloom's Taxanomy	Description
1	2	1	3	Application
2(i)	3	1	4	Analysis
2(ii)	3	1	3	Application
3	4	1	5	Evaluation
4(i)	5	2	3	Application
4(ii)	5	2	5	Evaluation
4(iii)	5	2	2	Comprehension
5	6	1	3	Application

Table 6: Entry number for each question for Linear Algebra pre-test

Question	CO	PO	Level of Bloom's Taxanomy	Description
1(i)	1	1	1	Knowledge
1(ii)	1	1	2	Comprehension
1(iii)	1	1	3	Application
2	2	1	2	Comprehension
3(i)	3	2	3	Application
3(ii)	3	2	2	Comprehension
4(i)	4	2	3	Application
4(ii)	4	2	2	Comprehension
5	5	1	2	Comprehension

Table 7: Entry number for each question for differential equation pre-test

Question	CO	PO	Level of Bloom's Taxanomy	Description
1	1	1	2	Comprehension
2	2	1	3	Application
3	2	1	3	Application
4(i)	3	2	1	Knowledge
4(ii)	3	2	2	Comprehension
4(iii)	3	2	3	Application
4(iv)	3	2	4	Analysis
5	4	2	3	Application
6(i)	5	1	3	Application
6(ii)	5	1	3	Application

Fig. 1 shows the person item distribution map or the wright map for the Vector Calculus subject. This map shows the students' problem-solving ability and the difficulty of the items or pre-test questions on a vertical line. The students' metric number is given on the left side of the vertical line. The pre-test question number is indicated on the right side of the line.

The questions' difficulty level can be grouped into four. They are very difficult, difficult, moderate and easy. Question 4(iii) belongs to the very difficult group. Question 1, question 3 and question 4(ii) fall into the 'difficult group'. Both difficult and very difficult group are above the mean line. Two groups are below the mean line. These are moderate and easy groups. Question 2(i) and question 2(ii) were considered average for students to solve. Meanwhile, question 4(i) and question 5 are the easiest questions for the students.

Fig. 2 shows the person item distribution map for the Linear Algebra pre-test. Since the number of students in the pre-testis 282, all their metric number is not shown in Fig. 2. Instead that, "#" represents 5 students. Below than 5 students, it will be represented by ".".

The level of difficulty of the pre-test questions can be divided into 3 groups. Questions above the mean line are defined as 'mediocre' and 'very difficult' category. From a total of 9 questions 4 questions fall into 'mediocre' category whereas 2 questions fall into 'very difficult' category. Among the questions fall into 'mediocre' category are question 1(ii), question 3(i), question 4(i) and question 4(ii). Question 2 and question 5 grouped into 'very difficult' category.

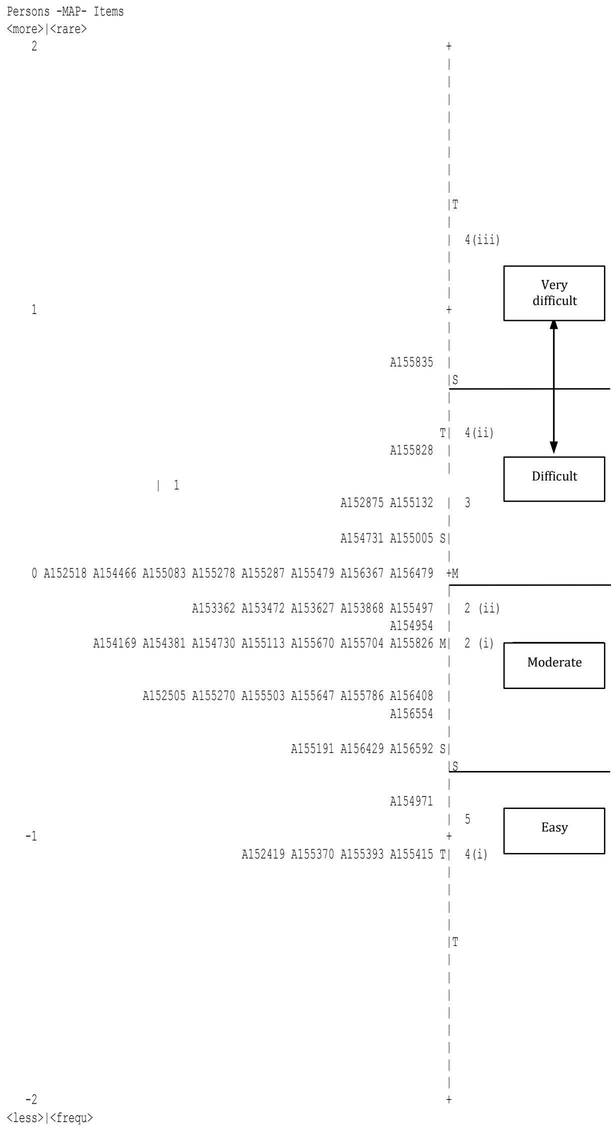

Fig. 1: Person item distribution map for vector calculus pre-test

On the other hand, questions below mean line are easy for students to answer during the pre-test. Students find that is not difficult to answer question 3(ii), question 1(i) and question 1(iii).

Fig. 3 shows the person item distribution map for the Differential Equation pre-test. The pre-test questions can be separated into four groups. They are very difficult, difficult, moderate and easy. Question 4(iv), question 4(iii) and 6(ii) are very challenging for the engineering students. Question 4(ii), question 3, question 6(i) are very challenging for the engineering students. Question 4(ii), question 3, question 6(i) and question 2 grouped in difficult category. Question 5 was a moderate one. In the pre-test, question1 and question 4(i) are the easiest for the students to answer.

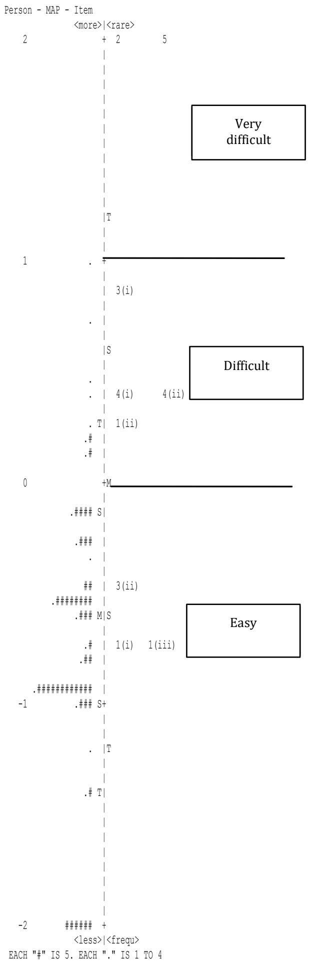

Fig. 2: Person item distribution map for linear algebra pre-test

The overall difficult and very difficult questions for Vector Calculus, Linear Algebra and Differential Equation subjects are identified as the difficult course outcomes for Engineering Mathematics. From this result, 8 lab sessions will be suggested for engineering students. Table 8 summarizes the suggested lab sessions for Engineering Mathematics.

Recently many researchers have conducted lab sessions on Vector Calculus subject and positive feedback received from them. Botana et al., 2014, Noinang et al., 2008, and Adair and Jaeger, 2014 are the latest researchers who have conducted lab sessions to teach Engineering Mathematics. Better understanding on the conceptual and procedural knowledge, software tools help in visualization and saving a lot of time from computation are the general comments received from the students.

Among the researchers who has conducted laboratorial sessions for Linear Algebra subject, commented on students agreed that the abstract concept of Linear Algebra can be understood clearly with the help of software (Schmidt et al., 2008; Chen, 2013). Students also were very actively involved in group activities.

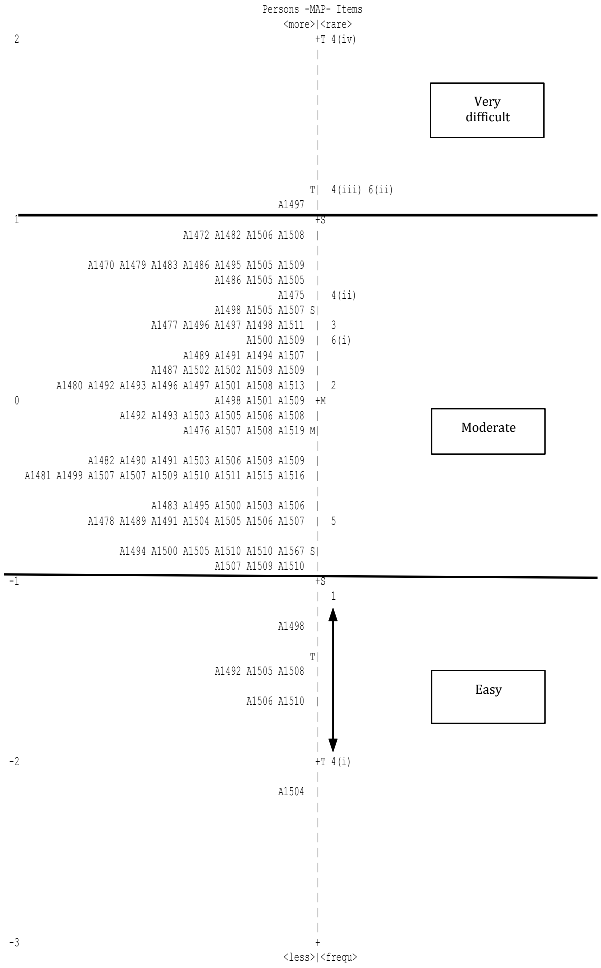

Fig. 3: Person item distribution map for differential equation pre-test

Table 8: Suggested lab sessions for engineering mathematics

Lab	Description
1	Able to apply the basic concepts of partial derivatives.
2	Able to apply the concepts of line integral, double integral and triple integral in solving engineering problems.
3	Able to apply Green's Theorem, Stokes' Theorem and Gauss Theorem in solving engineering problems.
4	Able to use the concepts of vector space, linear independent in the space dimension transformation.
5	Able to understand the concepts of power series.
6	Able to solve first and second order of differential equations.
7	Able to perform step-by-step analysis to model the simple engineering problem using differential equations and to solve the differential equations using an appropriate technique.
8	Able to use Fourier series to solve partial differential equations.

Some of the latest researches who incorporated computational tool in teaching Differential Equation proved that computational tools improved students' understanding on the Differential Equation subject (Maat and Zakaria, 2011; Zeynivannezhad, 2014; Shacham et al., 2008).

It also developed creative thinking among students. Computational tools help to visualize the graphs in the subject.

4. Conclusion

This study introduces the lab session for Engineering Mathematics subjects namely Vector Calculus, Linear Algebra and Differential Equation.

The Rasch model was used to analyze the pre-test results. Person item distribution map classify the pre-test questions into different categories. All difficult and very difficult course outcome category questions are chosen for the lab sessions. 8 lab sessions are identified with the Bloom Taxanomy level.

From this study, 3 difficult course outcomes for Vector Calculus, 3 difficult course outcomes for Linear Algebra and 2 difficult course outcomes for Differential Equation were identified. Lab sessions are aimed to help students to improve their problem-solving ability. It is hoped that students can gain better conceptual understanding of the subjects through the lab sessions.

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