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An Improved Course Assessment Measurement for Analyzing Learning Outcomes Performance Using Rasch Model

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Abstract

Course Learning Outcomes (CLO) shall be used to state the expected knowledge that the student supposed to acquire at the end of the semester and shall be outlined according to the Bloom Taxonomy. Students can estimate the level of their knowledge and skills that were obtained at the end of each course using the CLOs. Unfortunately, there was no formal method for measuring performance of CLO for each course. The usual procedure is to distribute questionnaires to the students manually or via online. Students provide their performances for the CLO using a likert scale. The questionnaire’s outcomes are the students’ estimation of the level of their knowledge and skill obtained from a particular course. Unfortunately, this method cannot accurately portray the students’ performances through actual evaluation. Therefore, this paper aims to measure the effectiveness of the teaching and learning method by measuring the performance of the CLO using Rasch model. The methodology for this study consists of three phases, which are planning, classification and result analysis. The output of this study is the actual students’ performances for the CLO for all courses. The results from this study can guide the lecturer to monitor the performance for each CLO and consequently leading towards improvements in the taught courses.

Keywords: Course learning outcomes; Rasch model; Bloom taxanomy; Measurement; Student performance;

1. Introduction

According to the Malaysian Qualification Framework (MQF), the educational standardization process must be according to outcome based education (OBE) (Abdul Aziz et al., 2007). OBE is an educational process that focuses on achieving a particular outcome or skill that should be grasped by each student at the end of the course. Each student should be able to achieve this outcome or corresponding skill level. The OBE approach is significantly different from the traditional approach. Through this approach, the teaching and learning plan is performed after determining the skills that will be instilled for students in a particular course. Then, the teaching method will be designed to help students achieve a particular skill or course learning outcome (CLO).

This commendable practice has been adopted in the teaching and learning process in all faculties in Universiti Kebangsaan Malaysia (UKM) including Faculty of Information Science and Technology (FTSM). This is in line with the ISO 9001:2000 standards. CLO can also guide the students to recognize the skills that they will gain for each course they participated in. The student’s ability to achieve the CLO can indicate how far the students can implement the required skills and also to measure the effectiveness of teaching. This paper aims to measure the effectiveness of the teaching and learning method by measuring the performance of the CLO. Similar studies were performed by other researchers (New Straits Times, 2009; Ahmad et al., 2009). This study uses a course TC1243 Knowledge Engineering Methodology as its domain. This course is one of the courses offered to the first year students from the Intelligent Systems Program at the Faculty of Information Science and Technology.

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To date, there are no specific measurements for measuring CLO performance. Therefore, it is quite difficult to know the actual performance for each CLO. On the other hand, evaluation via quizzes, projects and exams are not associated with the CLO performance. The current practice to measure the CLO performance is by distributing questionnaire to students during the final week of the semester. This questionnaire lists the CLO that the students must use to evaluate their own understanding of the predetermined CLO for the course. Students are expected to answer the questionnaire to measure how much that they have accomplished for each CLO using a Likert Scale: 1 to 5 (Not Achieved, Not Quite Achieved, Moderately Achieved, Quite Achieved, Successfully Achieved). However, this practice was unsuitable for measuring the CLO performances of the students because it was only based on the students’ views and assumptions (Bradley et al., 2010). Hence, another method is needed to measure the CLO performance for each student. In this study, a measurement method using the Rasch Model is proposed. This model can be used to analyze data for evaluating, performance or skill measuring and has previously used in the health sector, market study and psychometrics. The purpose of measuring CLO using Rasch Model is to construct a better learning process and better result compared to other traditional testing methods which do not provide proper mechanism with high accuracy and not consistent to produce evaluation of CLO based on students’ perceptions. The Rasch Model is expected to accurately measure the CLO performance as compared to the traditional methods.

3. Measuring CLO using Rasch Model

Rasch Model is a one-parameter logistic and static model within item response theory (IRT) in which the amount of a given latent trait in a person and the amount of the same latent trait reflected in various items can be estimated independently yet still compared explicitly to one another (Bradley et al. 2010). Through Rasch Model, each person with a certain amount of a given latent trait specifies the probability of a response in one of the categories of an item. Rasch measurement for CLO assessment brings an opportunity to Learning Performance Measurement System (LPMS) in Malaysian Institution of Higher Learning (IHL) to be able to evaluate the quality of learning performance. Rasch Model which is used to indicate an ability for a given task, is given as follows:

\[
P_r\{x_i = 1\} = \frac{e^{\beta_v - \delta_i}}{1 + e^{\beta_v - \delta_i}}
\]

where \(e\) = Euler’s number, 2.71828;
\(\beta_v\) = the ability of person \(v\);
\(\delta_i\) = the difficulty of assessment item \(i\).

The equation above can be further simplified to measure probability of success by introducing log function [5]. The probability of success or known as logit is predicted by the difference between ability measurement and item difficulty as shown below:

\[\text{Logit}(P/1-P) = \beta_v - \delta_i\] (2)

Thus, the probability for a CLO achievement can be summarized as below:

\[
\text{Probability of success for a CLO} = \frac{\text{Ability of a student}}{\text{Difficulty of a given task}}
\]

The probability of success for each CLO shows a relationship of student’s ability in response to the difficulty of CLOs.

4. Methodology

The work consists of three phases which are planning, classification and results analysis. In the planning phase, the research domain was identified and each question sheet was evaluated. The test specification on CLO is established and the data classifications based on the tabulation students’ assessment results on each CLO is formulated. Then data were transformed to the dataset that based on grade rating of mark cluster. The transformed data will be treated as input into WinSteps 3.69 software. The results were then analyzed and the phases involved are described below.
4.1 Planning Phase

This phase starts with the identification of the research domain. TC1243 Knowledge Engineering Methodology module was chosen for research domain and the course learning outcomes (CLO) for this module were examined. In brief, the course has an aim to teach students on the expert system development methodology by using an expert system development life cycle. The developments of the CLO for this course are according to Bloom taxonomy level as shown in Table 1. Bloom’s Taxonomy cognitive learning levels which are knowledge, understand, apply, analyze, evaluate and synthesis, are applied to CLOs of the course. In this course, a number of evaluation methods were used to test student’s understanding on the taught materials. The assessment comprises of quizzes (15%), assignments (15%), projects (20%) and the final exam (50%).

Table 1. CLO for TC1243 Knowledge Engineering Methodology

| CLO  | Course Learning Outcome (CLO)                                                                 | Bloom taxonomy |
|------|-----------------------------------------------------------------------------------------------|----------------|
| CLO1 | Able to identify and explain project justification that is suitable for knowledge based system (KBS) | Knowledge (C1) |
| CLO2 | Able to apply knowledge engineering methodology in the planning and designing KBS on certain domain | Application (C2) |
| CLO3 | Able to acquire knowledge from the expert domain or other resources efficiently.               | Analysis (C3)  |
| CLO4 | Able to represent and identify best approaches in organizing and knowledge decision representation. | Evaluate (C4)  |
| CLO5 | Able to manage and coordinate KBS based project efficiently.                                   | Synthesis (C5) |

4.2 Classification phase

This phase focuses on the pre-processing on the total number of seventeen students, who enrolled for this course. The number of activities in this phase includes:

a. Quizzes, assignments, project and final exam are collected to identify the CLO level for each question.
b. Students’ marks for all evaluation categories were collected according to CLO level.
c. Students’ marks are allocated according to grade. These grades will be taken as input to the Winstep software.

Using the Rasch Model an analysis on the students’ achievement in learning can be determined and development of students’ cognitive skills can also be analysed by examining the level of evaluation difficulties. The formula used in this model in measuring CLO achievement is described using equation (3).

Measurement for each CLO is one of the attributes to identify the achievement level in TC1243 course. This process is illustrated in the diagram as shown in Figure 1

Figure 1 CLO measurement methods using Rasch Model.
Seventeen students who enrolled in TC1243 Knowledge Engineering Methodology during the second semester of the 2009/2010 session were chosen as the samples in the study. All the questions used in quizzes, assignment, project and final exam are identified and classified according to CLO level. Based on the classification, the percentages distribution of each question according to CLO was summarized as shown in Table 2.

Table 2. Percentage distribution according to CLO

| Evaluation | Quiz (15%) | Project (20%) | Assignments (15%) | Final Exam (50%) | 100% |
|------------|------------|---------------|--------------------|------------------|------|
| CLO1       | 0.18       | 0.00          | 0.00               | 0.50             | 27.7 |
| CLO2       | 0.58       | 0.00          | 0.15               | 0.20             | 21.0 |
| CLO3       | 0.14       | 0.00          | 0.59               | 0.00             | 11.0 |
| CLO4       | 0.10       | 0.00          | 0.25               | 0.30             | 20.3 |
| CLO5       | 0.00       | 1.0           | 0.00               | 0.00             | 20.0 |
| Check      | 1.0        | 1.0           | 1.0                | 1.0              | 100.0|

Marks percentage distributions according to CLO were then counted. Each evaluation marks for each CLO was summed up and divided by the whole total for each CLO. Table 3 describes marks distribution for students according to CLO. We also performed an evaluation according to gender (1 for female and 2 for male), which aims to see a difference between gender in the achievement during a learning process.

Table 3. Marks distribution according to CLO

| Student | Gender | CLO1 | CLO2 | CLO3 | CLO4 | CLO5 |
|---------|--------|------|------|------|------|------|
| STD01   | 2      | 79.6 | 65.5 | 62.0 | 68.8 | 88.6 |
| STD02   | 1      | 65.3 | 56.9 | 79.6 | 83.3 | 82.9 |
| STD03   | 1      | 51.0 | 53.4 | 77.8 | 59.4 | 82.9 |
| STD04   | 2      | 67.3 | 67.2 | 50.9 | 79.2 | 82.9 |
| STD05   | 2      | 58.2 | 44.8 | 62.0 | 87.5 | 88.6 |
| STD06   | 1      | 26.5 | 49.1 | 76.9 | 70.8 | 94.3 |
| STD07   | 1      | 44.9 | 44.0 | 77.8 | 63.5 | 82.9 |
| STD08   | 2      | 56.1 | 52.6 | 76.9 | 66.7 | 94.3 |
| STD09   | 2      | 44.9 | 41.4 | 58.3 | 72.9 | 88.6 |
| STD10   | 1      | 61.2 | 58.6 | 75.0 | 72.9 | 94.3 |
| STD11   | 1      | 39.8 | 65.5 | 50.9 | 52.1 | 82.9 |
| STD12   | 1      | 39.8 | 44.8 | 29.6 | 47.9 | 74.3 |
| STD13   | 2      | 33.7 | 64.7 | 47.2 | 70.8 | 82.9 |
| STD14   | 2      | 87.8 | 52.6 | 27.8 | 66.7 | 74.3 |
| STD15   | 1      | 62.2 | 34.5 | 25.9 | 68.8 | 74.3 |
| STD16   | 1      | 61.2 | 43.1 | 77.8 | 72.9 | 82.9 |
| STD17   | 2      | 26.5 | 62.1 | 49.1 | 63.5 | 82.9 |

Marks for each CLO were then assigned according to grade based on the category below.

\[
F(x) = \begin{cases} 
0 & \text{if } 0 \leq x < 40; \\
1 & \text{if } 40 \leq x < 50; \\
2 & \text{if } 50 \leq x < 60; \\
3 & \text{if } 60 \leq x < 70; \\
4 & \text{if } 70 \leq x < 80; \\
5 & \text{other}; 
\end{cases}
\]
These CLO marks were then mapped into a grade category before it is processed into the Winstep software. Results from the mapping process were shown in Table 4.

| Student | Gender | CLO1 | CLO2 | CLO3 | CLO4 | CLO5 |
|---------|--------|------|------|------|------|------|
| STD01   | 2      | 4    | 3    | 3    | 3    | 5    |
| STD02   | 1      | 3    | 2    | 4    | 5    | 5    |
| STD03   | 1      | 2    | 2    | 4    | 2    | 5    |
| STD04   | 2      | 3    | 3    | 2    | 4    | 5    |
| STD05   | 2      | 2    | 1    | 3    | 5    | 5    |
| STD06   | 1      | 0    | 1    | 4    | 4    | 5    |
| STD07   | 1      | 1    | 1    | 4    | 3    | 5    |
| STD08   | 2      | 2    | 2    | 4    | 3    | 5    |
| STD09   | 2      | 1    | 1    | 2    | 4    | 5    |
| STD10   | 1      | 3    | 2    | 4    | 4    | 5    |
| STD11   | 1      | 0    | 3    | 2    | 2    | 5    |
| STD12   | 1      | 0    | 1    | 0    | 1    | 4    |
| STD13   | 2      | 0    | 3    | 1    | 4    | 5    |
| STD14   | 2      | 5    | 2    | 0    | 3    | 4    |
| STD15   | 1      | 3    | 0    | 0    | 3    | 4    |
| STD16   | 1      | 3    | 1    | 4    | 4    | 5    |
| STD17   | 2      | 0    | 3    | 1    | 3    | 5    |

5. Results and Discussion

A set of data consists of seventeen students and their assessment result tabulation is processed as an input data using WinSteps 3.69 software to compute the related result. After the input data is processed, the Person-Item Distribution Map (PIDM) is generated by the software. Figure 2 shows each student (Person=STD nn GenderX) location related to the CLOs distribution (Item). The PIDM maps out the distribution of Person and Item on the same logit scale in line with the Latent Trait Theory. The PIDM indicates an ability $\beta$ of a person $v$ in response to the difficulty $\delta_i$ of an item $i$. Thus, the parameter $\beta$ is the location of the item on the same trait: if $\beta_v$ is greater than $\delta_i$, then the person is likely to be able to respond to the item correctly (Rashid & Zaharim, 2007). The degree of a person's ability is indicated by the separation of the item against the person’s location on the map: the further the separation, the more able a person likely to respond correctly to the said item (Rashid & Zaharim, 2007). Meanwhile, the difficulty of an item depends on the spread of the item over a scale. For instance, the further the location from the Mean$_{item}$, then the more difficult the item as compared to an item located nearer. In this paper, the Mean$_{item}$ is set to zero where it serves as the threshold on the logit scale.

![Figure 2 Person-item distribution map](image-url)
In order to measure the achievement of each student and CLO in the PIDM, the logit values are generated as shown in Table 5 and Table 6. The measurements of STD and CLO show logit value position for each student and CLO. From the PIDM, it shows that the cohort Mean$_{person}$ = 0.58 which is higher than the threshold value, Mean$_{item}$ = 0.00. This indicates that students have high abilities on given CLOs. Only two out of seventeen students (11.7%) were found to be below Mean$_{item}$. These two students are able to achieve CLO5 (Synthesis) but having difficulty to satisfy the rest of CLOs. Out of five CLOs, CLO1 (logit 1.34) and CLO2 (logit 1.39) appeared to be the two most difficult items. Most of the questions to test CLO1 and CLO2 are used in quizzes and final examination. During quizzes and final examination, students need to memorize the facts in order for them to answer the questions. This may cause difficulty to students where they need to answer the questions without referring to any books and notes. This may be the reasons why the CLO1 and CLO2 have a high logit values.

| Table 5. Logit Value for Each Student |
|--------------------------------------|
| Student   | Logit Value |
| STD021    | 1.67        |
| STD012    | 1.39        |
| STD101    | 1.39        |
| STD042    | 1.14        |
| STD161    | 1.14        |
| STD052    | 0.92        |
| STD082    | 0.92        |
| STD031    | 0.71        |
| STD061    | 0.51        |
| STD071    | 0.51        |
| STD142    | 0.51        |
| STD092    | 0.31        |
| STD132    | 0.31        |
| STD111    | 0.11        |
| STD172    | 0.11        |
| STD151    | -0.32       |
| STD121    | -1.53       |

| Table 6. Logit Value for each CLO |
|-----------------------------------|
| CLO                  | Logit Value |
| CLO 1- Identify and justify | 1.34        |
| CLO 2- Apply          | 1.39        |
| CLO 3- Acquire and Analyze | 0.83        |
| CLO 4- Evaluate       | -0.07       |
| CLO 5- Synthesis      | -3.48       |

The easiest item revealed in the PIDM is CLO5 (synthesis) with logit value of -3.48. CLO5 is evaluated based on knowledge-based system project. Although it should be the most difficult item to achieve in Bloom’s Taxonomy ranking, PIDM reveals it is well understood by all students. This is because the marks given for CLO5 is assessed not only based on the evaluation of paperwork, but also attitude, cooperative and efforts of students in completion of the project. Overall, distribution of student in relation to CLO is mostly concentrated above threshold value. For instance, student STD021 has the highest position among other students. He has good achievement over all the expected CLO performance with logit value 1.67. The poorest student STD121 (logit -1.53) needs to put more efforts where he only able to fulfil CLO5 (Synthesis).

Winstep software provides a function calls Differential Item Function (DIF). With this function, the PIDM is able to differentiate learning ability between genders. For example, male students STD142, STD092, STD132 and STD172 are of low ability, as their logit value below the Mean$_{person}$ = 0.58. Compare to male students, there are five female students STD061, STD071, STD111, STD151, STD121 that positioned below Mean$_{person}$. However, a male student STD021 has the highest position possessing high ability in the PIDM.

Table 7 shows the probability of each student in achieving each CLO respectively. It details out the analysis of correlation of each person to each item by computing the probability of CLOs achievement for every student. It can also be calculated
manually by using equation (1) and (2). Taking student STD021 as an example in calculating the probability of achieving CLO2, and from equation (2), the value of $P(\theta)$ will generate as follows:

\[
P(\theta) = \beta_v (\text{STD021}) - \delta_i (\text{CLO2})
\]

\[
= 1.67 - 1.39
\]

\[
= 0.28
\]

Substitute this value into equation (1):

\[
P(\theta) = \frac{e^{\beta_v \theta}}{1 + e^{\beta_v \theta}}
\]

\[
= 0.5695
\]

The value of 0.5695 will be the CLO2 achievement of student STD021. The rest of the analysis are shown in Table 7.

| Table 7. Probability of each student to achieve each CLO |
|---------------------------------------------------------|
| Probability of success | CLO 1 | CLO 2 | CLO 3 | CLO 4 | CLO 5 |
|-------------------------|-------|-------|-------|-------|-------|
| P(STD021)               | 0.58  | 0.57  | 0.70  | 0.85  | 0.99  |
| P(STD012)               | 0.51  | 0.50  | 0.64  | 0.81  | 0.99  |
| P(STD101)               | 0.51  | 0.50  | 0.64  | 0.81  | 0.99  |
| P(STD042)               | 0.45  | (0.44) | 0.58  | 0.77  | 0.99  |
| P(STD161)               | 0.45  | (0.44) | 0.58  | 0.77  | 0.99  |
| P(STD052)               | (0.40) | (0.39) | 0.52  | 0.73  | 0.99  |
| P(STD082)               | (0.40) | (0.39) | 0.52  | 0.73  | 0.99  |
| P(STD031)               | (0.35) | (0.34) | 0.47  | 0.69  | 0.99  |
| P(STD061)               | (0.31) | (0.30) | (0.42) | 0.64  | 0.98  |
| P(STD071)               | (0.31) | (0.30) | (0.42) | 0.64  | 0.98  |
| P(STD142)               | (0.31) | (0.30) | (0.42) | 0.64  | 0.98  |
| P(STD092)               | (0.27) | (0.26) | (0.38) | 0.59  | 0.98  |
| P(STD132)               | (0.27) | (0.26) | (0.38) | 0.59  | 0.98  |
| P(STD111)               | (0.23) | (0.22) | (0.33) | 0.54  | 0.97  |
| P(STD172)               | (0.23) | (0.22) | (0.33) | 0.54  | 0.97  |
| P(STD151)               | (0.16) | 0.54  | (0.24) | (0.44) | 0.96  |
| P(STD121)               | (0.05) | (0.05) | (0.09) | (0.19) | 0.88  |

From Table 7, it can be concluded that out of 17 students, there are only three students (17.6%) have no problems with their CLOs achievement. The rest 14 students mostly are having difficulty in achieving CLO1 (Identify and justify) and CLO2 (Apply) where the probability of achieving CLO below 0.45 is put in parentheses. The best CLO achievement is CLO5 (Synthesis) where all students can achieve well based on the probability shown. The table concludes that all students able to achieve the high CLO rather than the low CLO. This is a normal phenomena because CLO5 (Synthesis) is only tested in group project whereas other CLOs are tested in the quiz, assignment and final examination. Ample time is given to the students to plan, discuss and complete the group projects. Compare to quiz, assignment and examination, the exercises are done individually under exam like environment.

6. Action Plan

Several suggestions for this study were outlined to improve the teaching and learning quality such as:

i. Course CLO must be developed thoroughly so that it encompasses all levels from the Bloom taxonomy.

ii. A more exact mechanism for measuring the course performance. This study proposed the use of the Rasch model that can accurately measure the CLO performance as compared to traditional methods.

iii. Each evaluation using quizzes, assignments, projects or examination must be able to evaluate students based on CLO stated for the course.
It is hoped that with these suggestions, the CLO measurement can be improved. This will help the lecturer to identify the weaknesses in his/hers teaching methods and to improve the weakness for the benefit of the students.

7. Conclusion

This study has proven that using the Rasch Model for measuring the CLO performance for TC1243 Knowledge Engineering Methodology is more accurate. Such measurement is better when compared to traditional methods that only measure the CLO based on the students’ assumption using the distribution of questionnaire forms. This model is able to produce the association pattern between students and the performance level for each CLO. This pattern cannot be produced using standard measurement method. The results from this study can guide the lecturer to monitor the performance for each CLO outlined for a course. CLO performance reflects the effectiveness of the lecturer’s teaching method besides identifying weak students.

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