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DIRECT ASSESSMENT OF STUDENT OUTCOMES IN OBJECT-ORIENTED DESIGN COURSE USING RASCH MODEL ANALYSIS

ZUHAIRA M. ZAIN*

Information Systems Department, College of Computer & Information Sciences,
Princess Nourah Bint Abdulrahman University, Riyadh, Saudi Arabia
*Corresponding Author: zmzain@pnu.edu.sa

Abstract

Student outcomes (SOs) allow students to identify their ability for each course they registered as well as to quantify the teaching efficacy. There are two methods to assess SOs, which are the direct assessment (which typically depends on coursework) and the indirect assessment (which is typically obtained through survey). This study specifically focused on direct assessment, which considered students' coursework according to a particular target. However, the established target may be unrealistic. Moreover, the actual achievement scores were recorded and averaged based on the average scores in the direct assessment process, which is considered inaccurate. Thus, this study aimed to examine the attainment of SOs using the Rasch model. Specifically, this study proposed a systematic process, which comprised of planning, classification, and analysis. The resultant outcome of this process was the attainment of SOs for the IS223D course. This assists teaching staff in monitoring the attainment of SOs and subsequently improves the instructed course. This study also reaffirmed the accuracy of the assessment of SOs using the Rasch model compared to the conventional approaches that are based on unrealistic target and inaccurate process of averaging the average scores.

Keywords: ABET, Direct assessment, Rasch model, Students' achievement, Students outcomes.

1. Introduction

Academic programs around the world must fulfil the General Criteria to acquire accreditation from the Computing Accreditation Commission of Accreditation Board for Engineering and Technology (ABET). The General Criteria comprises eight criteria, which are (1) students, (2) program educational objectives, (3) student outcomes, (4) continuous improvement, (5) curriculum, (6) faculty, (7) facilities, and (8) institutional support. Continuous improvement is one of the important criteria in the General Criteria, in which suitable, recognized procedures must be regularly applied to evaluate the extent to which student outcomes (SOs) of a program are achieved. Assessment results on SOs are then used as input for the continuous improvement of ABET accredited program [1].

According to ABET [1], students in an academic program must attain nine SOs upon graduation, which are (a) able to apply knowledge of computing and mathematics according to their discipline and established SOs of the program, (b) able to apply analytical thinking skills for problem solving as well as to identify and define computing requirements appropriate to its solution, (c) able to design, implement, and evaluate computer-based system, process component, or program to meet desired needs, (d) able to effectively function in a team environment towards a common goal, (e) good grasp of understanding pertaining to ethical, legal, professional, security, and social issues and responsibilities, (f) able to communicate effectively with a wide range of audiences, (g) able to analyse local and global impacts of computing on individuals, organizations, and society, (h) recognition of the need for and able to engage in continuous professional development, and (i) able to apply current techniques, skills, and tools necessary for computing practice. These SOs distinguish the achievement of students in terms of their ability for every course they registered. The ability of students to attain these SOs demonstrates the extent of these students in applying the necessary skills. Such measurement is deemed to be also useful in evaluating the effectiveness of teaching.

The assessment of SOs at the end of every academic semester can be performed in both ways. Firstly, SOs can be directly assessed, which typically relies on coursework. Secondly, indirect assessment of SOs, which is typically obtained through survey. For this study, the direct assessment of SOs was specifically considered. In particular, the scores of the students' coursework were used to evaluate SOs. The coursework generally consists of assignments, exams, projects, quizzes, and all relevant activities that directly contribute to students' achievement for the particular semester. Direct assessment of SOs typically refers to the evaluation of each SO according to the established target of program or expected level of attainment. However, the established target may be unrealistic because it usually refers to the previously established target or the established target of other ABET accredited program. According to TKI [2], the establishment of target is principally simple, but poses challenges in actual practice because most of these targets do not imply enriched attainment. Besides that, direct assessment process considers the average of the average scores of students' coursework, which is reportedly inaccurate [3] and erroneous [4].

Addressing that, this paper proposed a systematic process to evaluate the attainment of SOs using the Rasch model. The proposed process was expected to precisely assess the attainment of SOs compared to the conventional approaches that are based on unrealistic target and the average of the average scores of students.

Wright and Mok [5] emphasized the Rasch model fulfils the guidelines, in which a measurement model must yield linear measures, solves missing data, provides accurate estimation, detects misfits, and distinguishes the parameters of the assessed object from those of measuring tool. Consequently, significant inferences can be produced with the transformation of an ordinal score into a linear, interval-level variable by estimating the fit of data to the expectations of Rasch model. Besides that, the model has been used to assess the reliability and quality of examination papers [6-12] as well as the performance of students according to the Course Learning Outcomes (CLO) [13], but not for the evaluation of their attainment of SOs. Essentially, the model is considered reliable and suitable for the measurement of students' ability [7, 9, 10]. Adding to that, Aziz et al. [14] identified that the model's person-item distribution map (PIDM) provides accurate synopsis of students' attainment on a linear scale of measurement. PIDM also provides significant report on students' learning efficacy [15].

2. Rasch Model in Measuring SOs

The basic underlying principle of Rasch model is that the probability of a student successfully verifies a particular item is governed by the difference between the difficulty of the particular item and the ability of the student [16-18]. The rationalization of this principle is that students have higher probability of answering items of lower difficulty and lower probability of answering items of higher difficulty accurately [16], which is mathematically expressed in the following:

$$P_r\{x_1 = 1\} = \frac{e^{\beta v - \delta_i}}{1+e^{\beta v - \delta_i}} \quad (1)$$

where

β_v = the ability of student *v*

δ_i = the difficulty of SO *i*

This study introduced log function to further simplify the aforementioned equation in measuring the probability of success [16-18]. The probability of success or recognized as *logit* is estimated based on the variance between the measured ability of students and the difficulty of SOs, which is expressed as follows:

$$Logit(P/1-P) = \beta_v - \delta_i \quad (2)$$

where

$Logit(P/1-P)$ = probability of a student's success for each SO

The probability of students' success for each SO demonstrates the relationship between the ability of students and the difficulty of given task for SOs. More specifically, the underlying logic of this equation is that in the context of SOs, students have higher probability of success in achieving easier tasks and lower probability of success in achieving difficult task.

3. Methods

The application process of Rasch model for the assessment of SOs in this study is presented in Fig. 1. The process comprised of three stages, which were (1) planning, (2) classification, and (3) analysis. Generally, this study firstly established the research domain and measured each assessment tool. Subsequently, this study determined the test specification on SOs and classified the data according to the statistics of the assessment results for each SO. Following that, this study converted the data into dataset according to the mapping of grade and rating scale prior to the utilization of these converted data as input for the Bond&Fox Steps software. The obtained results were then analysed and interpreted. The detailed description of these three stages are provided in the following sub-sections.

3.1. Planning

In this phase, the research domain was determined. The IS223D (Object-oriented Design) course was selected as the research domain for this study. The SOs of this course were subsequently identified. This course is one of the core subjects in the Information Systems (IS) program, which is available in the College of Computer and Information Sciences at Princess Nourah bint Abdulrahman University (PNU). Zain [11] explained this course must be completed by the IS students prior to graduation, which aims to introduce diverse UML diagrams for the students to apply in the Object-oriented Software Development environment.

The course specialists performed the mapping of SOs that were approved by the respective departmental council for this course. In reference to the nine SOs previously presented, the SOs for this course emphasized on the second and third SOs: (b) able to apply analytical thinking skills for problem solving as well as to identify and define computing requirements appropriate to its solution and (c) able to design, implement, and evaluate computer-based system, process, component, or program to meet desired needs.

Several assessment tools were applied to examine students' understanding of the taught course. Basically, the evaluation comprised of quiz (10%), assignments (25%), project (10%), mid-term examination (15%), and final examination (40%). Table 1 displays the distribution of scores for each SO and assessment tool. The selection of samples for this study was also performed in this phase. In particular, this study considered convenience sampling strategy for the selection of samples given the constraints of cost and time. This particular sampling strategy was considered due to its low cost and efficiency. This study successfully sampled 25 IS223D students in their second academic semester of 2016-2017.

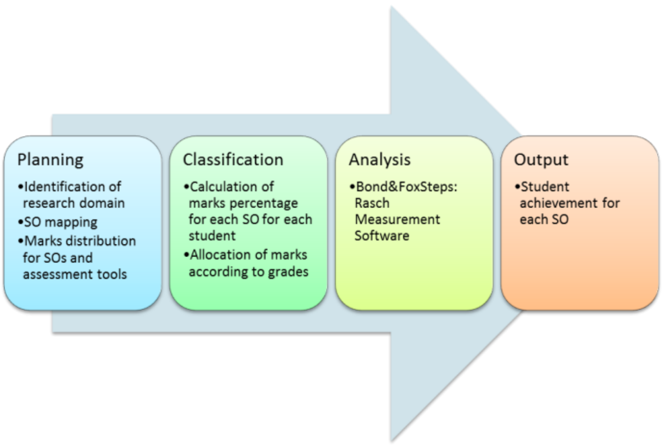

Fig. 1. Assessment process of SOs using Rasch model.

Table 1. Distribution of scores for each SO and assessment tool.

SO	Qu-iz	Assign-ment 1	Assign-ment 2	Project	Mid-term Exami-nation	Final Exami-nation	Total
b	10	1	6	4	8	15	44
c	0	4	14	6	7	25	56
Total	10	5	20	10	15	40	100

3.2. Classification

This stage specifically focused on the pre-processing of the sample. The scores in percentage for each SO were computed for each student. Each assessment score of each SO was then divided by the total of each SO. The distribution of actual scores for each SO are shown in Table 2. Students' scores for each SO were then graded according to the mapping guideline in Table 3. This mapping guideline is based on the Standard Grading of PNU. Meanwhile, Table 4 demonstrates the results of the mapping process. The dataset of the grade rating was tabulated in Excel*prn format prior to the analysis using the Bond&Fox Steps software.

Table 2. Achievement of SOs for each student.

Student	Achievement of SOs (%)	
	b	c
S01	88	73
S02	66	56
S03	74	65
S04	65	58
S05	63	56
S06	94	89
S07	62	66
S08	78	73
S09	88	77
S10	81	71
S11	70	78
S12	83	67
S13	78	80
S14	87	80
S15	57	50
S16	91	78
S17	63	54
S18	88	86
S19	97	92
S20	80	70
S21	62	69
S22	91	88
S23	84	77
S24	86	67
S25	90	89

Table 3. Mapping of grade and rating scale.

Grade	0-59	60-69	70-79	80-89	90-100
Rating scale	1	2	3	4	5

Table 4. Rating of SOs according to grade.

Student	Rating of SO according to grade	
	b	c
S01	4	3
S02	2	1
S03	3	2
S04	2	1
S05	2	1
S06	5	4
S07	2	2
S08	3	3
S09	4	3
S10	4	3
S11	3	3
S12	4	2
S13	3	4
S14	4	4
S15	1	1
S16	5	3
S17	2	1
S18	4	4
S19	5	5
S20	4	3
S21	2	2
S22	5	4
S23	4	3
S24	4	2
S25	5	4

3.3. Analysis

In this phase, the obtained results were analysed and interpreted. The discussion on these results is presented in the subsequent section.

4. Results and Discussion

Figure 2 displays the summary statistics for two SOs achieved by 25 selected IS223D students in this study. The values of mean square and z-statistic were closer to their expected values, +1 and 0, respectively for item and person, which indicated that the model is satisfactory fit. Besides that, the reliability values of item and person recorded 0.95 and 0.88, respectively, which verified that the instrument is reliable, reproducible, and valid for measurement in assessing the attainment of SOs for IS223D course.

```
+-----------------------------------------------------------------------------+
| Persons      25 INPUT      25 MEASURED              INFIT          OUTFIT   |
|          SCORE     COUNT      MEASURE   ERROR      IMNSQ   ZSTD  OMNSQ   ZSTD|
| MEAN       6.2       2.0          .60    2.37        .71     .0    .74     .0|
| S.D.       2.0        .0         7.26     .97       1.76     .7   1.85     .7|
| REAL RMSE   2.56  ADJ.SD    6.79  SEPARATION  2.65  Person RELIABILITY  .88|
|-----------------------------------------------------------------------------|
| Items      2 INPUT        2 MEASURED                INFIT          OUTFIT   |
| MEAN      71.0      23.0          .00     .57        .87    -.2    .74    -.4|
| S.D.       9.0        .0         2.46     .01        .05     .1    .09     .2|
| REAL RMSE    .57  ADJ.SD    2.39  SEPARATION  2.42  Item   RELIABILITY  .95|
+-----------------------------------------------------------------------------+
```

Fig. 2. Summary of the statistics.

The PIDM representation for the analysis is portrayed in Fig. 3. Principally, PIDM places the ability of students (person) and SOs (item) on similar linear measurement scale. Referring to the map, the left region reveals the distribution of the students (person) and the right region presents the distribution of SOs (item). These distributions were found to be in line with the results of summary statistics presented in Fig. 2. The raw test scores of students as well as the performance of students presented on a linear scale are allowed to be included in the Rasch model analysis, which accounts for the unequal degree of difficulty across all items. The generated linear scale demonstrated that the Rasch model in this study satisfies the first criterion [5], which implies that a good measurement model must yield linear measures.

The separation of SOs versus the students' location on the map indicates the ability level of students. The further the separation is, the more competent a student is in achieving SO. The spread of SOs on the scale also reflects the degree of difficulty of SOs. The higher the location is from *MEANitem*, the higher the difficulty is in attaining SO. Thus, instead of establishing unrealistic target, *MEANitem* serves as a threshold, which was set as zero on the *logit* scale in this study. The placement of SO(c) was revealed to be at the top of item distribution, which implied that it was the most difficult to attain whereas SO(b) was found at the bottom of item distribution, which implied that it was the least difficult to attain. The obtained PIDM also confirmed that the person mean exceeded the threshold value (*MEANitem* equals to 0). In other words, the attainment of SOs exceeds the expected attainment of SOs.

Majority of the students (N = 17; 68%) were found to exceed the value of *MEANitem*, while eight students (32%) were found below the value of *MEANitem*. Students with lower ability encountered difficulty in achieving SO(c) (located above *MEANitem*). In order to measure SO(c), students were required to draw UML diagrams according to the given problems. This revealed that majority of these students had difficulty in drawing accurate UML diagrams. S15 had the lowest ability given that the student was at the bottom of student distribution. Conversely, S19 had the highest ability to attain both SOs since the student was at the top of the student distribution. In other words, the ability of this student surpasses the degree of difficulty of SOs. Besides that, the clear distribution of students and SOs verified that the Rasch model in this study fulfils another criterion [5], which implies that a good measurement model must distinguish the parameters.

Table 5 shows the estimation of Rasch item for the SOs of IS223D course, which presents a clearer presentation of the locations in the obtained PIDM; thus, corroborated the results of SOs. Specifically, the SO(b) was the least difficult to attain based on its position in the item distribution at -2.46 *logits*, while the SO(c), which was the most difficult to attain, was positioned at +2.46 *logits*.

Table 5. Item statistics.

Item	Measure	Model S.E	Infit		Outfit		PTMEA CORR.
			MNSQ	ZSTD	MNSQ	ZSTD	
c	2.46	.56	.83	-.4	.64	-.6	.94
b	-2.46	.59	.92	-.1	.83	-.1	.95

Note: The acceptable range for mean-square fit is between 0.6 and 1.4 [19]. The acceptable range for z-std fit is between -2 and +2 [16].

```
                           Persons -MAP- Items
                         <more ability>|<very difficult>
 13                              S19  +
                                      |
 12                                   +
                                      |
 11                                   +
                                      |
 10                    S06  S22  S25  +
                                      |
  9                                   +
                                      |
  8                                  S+
                                      |
  7                    S14  S16  S18  +
                                      |
  6                                   +
                                      |
  5                                   +T
                                      |
  4 S01  S09  S10  S13  S20  S23  +
                                      |
  3                                   +
                                      |S SO(c)
  2                                   +
                                      |
  1                S08  S11  S12  S24  +
                                     M|
  0                                   +M
                                      |
 -1                                   +
                                      |
 -2                              S03  +
                                      |S SO(b)
 -3                                   +
                                      |
 -4                                   +
                                      |
 -5                                   +T
                                      |
 -6                                   +
                                     S|
 -7                         S07  S21  +
                                      |
 -8                                   +
                                      |
 -9                                   +
                                      |
-10                                   +
                                      |
-11                                   +
                                      |
-12                S02  S04  S05  S17  +
                                      |
-13                                   +
                                      |
-14                                  T+
                                      |
-15                              S15  +
                         <less ability>|<very easy>
```

Fig. 3. PIDM.

Meanwhile, person statistics in measure order confirmed students' attainment of SOs, as portrayed in Table 6. The ability of S15 (-15.35 *logits*) and S19 (+13.44 *logits*), specifically, were validated. These results disclosed that the student with highest ability recorded maximum estimated measure, which suggested the ability of this student in attaining both SOs. Student with the lowest ability recorded minimum estimated measure, which suggested the inability of this student in attaining both SOs. The person fit statistics appeared satisfactory despite the need to re-examine S13. Referring to Guttman scalogram presented in Fig. 4, the results were counterchecked and confirmed that the student's achievement for the difficult SO(c) is higher than her achievement for the easier SO(b), while the achievement for other students was either vice versa or similar for both SOs.

Rasch person and item statistics confirmed that Rasch model fulfils another criterion as a good measurement model [5], which provides accurate estimation. Both person and item measures had an associated standard error (SE), indicating the precision of these measures. Besides that, the generated values of infit and outfit of mean-square in this study corroborated that the Rasch model detects misfits which is another criterion for a good measurement model [5]. A misfit presents if the values of infit and outfit of mean-square are not within the acceptable range. Wright et al. [19] commented the acceptable range for mean-square fit is between 0.6 and 1.4.

Basically, there are two types of misfit, which are (1) over fit - the values of IMNSQ and OMNSQ are below than the acceptable range and (2) under fit - the values of IMNSQ and OMNSQ exceed the acceptable range. It should be noted that the latter type requires further examination for its erratic performance.

Using Eqs. (1) and (2), the calculated values of probability of success (probability of each student to attain SO) are tabulated in Table 7. Taking the case of S19 as an example, the probability of S19 to attain SO(b), *P(θ)* was initially calculated using Eq. (2):

$P(\theta) = \beta_{S19} - \delta_b$ = 13.44 - (-2.46) = 15.9

This value was then substituted into Eq. (1):

$P(\theta) = \frac{e^{\beta v - \delta_i}}{1+e^{\beta v - \delta_i}}$ = 1

The probability of success for S19 to attain SO(b) equals to 1.

The equations demonstrated that the Rasch model does not consider the process of averaging the average of scores, which is reportedly inaccurate [3] and erroneous [4], to calculate the probability of success for students.

Based on Table 7, 13 out of 25 students (52%) were revealed to have no problem in attaining both SOs. Meanwhile, five students (20%) succeeded in attaining SO(b), but encountered problem in attaining SO(c). On the other hand, the remaining students (28%) encountered problem in attaining both SOs. In other words, these final remaining students failed to apply analytical thinking skills for problem solving as well as to identify and define computing requirements appropriate to its solution. Adding to that, they also failed to design, implement, and evaluate computer-based system, process component, or program to meet desired needs. Taking the Standard Grading of PNU as the reference for this study, score of less than 60 indicated failure; thus, the values of below 0.6 (probability of attaining SO) tabulated in Table 7 are put in parentheses to discriminate students' attainment of SOs, specifically of those who were likely fail to attain SOs.

Nonetheless, the obtained results of this study could not confirm that the Rasch model solves missing data because there were no missing data in this study. However, certain studies demonstrated that the Rasch model has the ability to handle missing data [20-23] by assigning unbiased score to every person who answers at least one of the items in a measure without loss of accuracy of measurement.

Table 6. Person statistics.

Person	Mea-Sure	Model S.E	Infit MNSQ	Infit Z-STD	Outfit MNSQ	Outfit Z-STD	PTMEA CORR.
S19	13.44	2.16	MAXIMUM ESTIMATED MEASURE				
S06	10.22	2.50	.06	-.1	.07	-.1	1.00
S22	10.22	2.50	.06	-.1	.07	-.1	1.00
S25	10.22	2.50	.06	-.1	.07	-.1	1.00
S14	6.85	1.52	.42	-.9	.42	-.9	.00
S16	6.85	1.52	2.24	1.6	2.24	1.6	1.00
S18	6.85	1.52	.42	-.9	.42	-.9	.00
S01	3.77	2.17	.02	-.4	.02	-.4	1.00
S09	3.77	2.17	.02	-.4	.02	-.4	1.00
S10	3.77	2.17	.02	-.4	.02	-.4	1.00
S13	3.77	2.17	8.56	2.2	9.06	2.3	-1.00
S20	3.77	2.17	.02	-.4	.02	-.4	1.00
S23	3.77	2.17	.02	-.4	.02	-.4	1.00
S08	.95	1.40	.81	-.5	.81	-.5	.00
S11	.95	1.40	.81	-.5	.81	-.5	.00
S12	.95	1.40	1.16	.6	1.16	.6	1.00
S24	.95	1.40	1.16	.6	1.16	.6	1.00
S03	-1.96	2.28	.04	-.3	.04	-.1	1.00
S07	-6.85	2.95	.06	.2	.06	.2	.00
S21	-6.85	2.95	.06	.2	.06	.2	.00
S02	-12.03	2.62	.08	.0	.08	.0	1.00
S04	-12.03	2.62	.08	.0	.08	.0	1.00
S05	-12.03	2.62	.08	.0	.08	.0	1.00
S17	-12.03	2.62	.08	.0	.08	.0	1.00
S15	-15.35	2.15	MINIMUM ESTIMATED MEASURE				

Note: The acceptable range for mean-square fit is between 0.6 and 1.4 [19]. The acceptable range for z-std fit is between -2 and +2 [16].

```
GUTTMAN SCALOGRAM OF RESPONSES:
Person |Item
       |bc
    19 +55  S19
     6 +54  S06
    22 +54  S22
    25 +54  S25
    14 +44  S14
    16 +53  S16
    18 +44  S18
     1 +43  S01
     9 +43  S09
    10 +43  S10
    13 +34  S13
    20 +43  S20
    23 +43  S23
     8 +33  S08
    11 +33  S11
    12 +42  S12
    24 +42  S24
     3 +32  S03
     7 +22  S07
    21 +22  S21
     2 +21  S02
     4 +21  S04
     5 +21  S05
    17 +21  S17
    15 +11  S15
```

Fig. 4. Guttman Scalogram.

Table 7. Probability of students to attain SOs.

Probability of Success	SO	
	b	**c**
P(S19)	1	0.999983
P(S06)	0.999997	0.999574
P(S22)	0.999997	0.999574
P(S25)	0.999997	0.999574
P(S14)	0.999909	0.987751
P(S16)	0.999909	0.987751
P(S18)	0.999909	0.987751
P(S01)	0.998034	0.787513
P(S09)	0.998034	0.787513
P(S10)	0.998034	0.787513
P(S13)	0.998034	0.787513
P(S20)	0.998034	0.787513
P(S23)	0.998034	0.787513
P(S08)	0.968016	(0.180939)
P(S11)	0.968016	(0.180939)
P(S12)	0.968016	(0.180939)
P(S24)	0.968016	(0.180939)
P(S03)	0.622459	(0.011891)
P(S07)	(0.012249)	(9.05E-05)
P(S21)	(0.012249)	(9.05E-05)
P(S02)	(6.98E-05)	(5.09E-07)
P(S04)	(6.98E-05)	(5.09E-07)
P(S05)	(6.98E-05)	(5.09E-07)
P(S17)	(6.98E-05)	(5.09E-07)
P(S15)	(2.52E-06)	(1.84E-08)

5. Action Plans

In order to improve the quality of teaching and learning, particularly in the IS223D course, several recommendations for the continuous improvement are presented in the following:

- Students should be exposed to more interactive problem-solving activities, including classroom discussions, to gain improved understanding on how to analyse a problem and present the correct UML diagram with respect to the given problem.
- Students should be given more class activities and lab exercises on drawing UML diagrams based on the given problem.

Besides that, in order to improve the evaluation process for the attainment of SOs, several recommendations are delineated:

- It is recommended to have a more rigorous procedure to assess the attainment of SOs. The process of applying Rasch model is considered to provide precise assessment on the attainment of SOs compared to the conventional approaches that are based on unrealistic target and average of average scores of students.
- It is essential to have proficient assessment tools to assess the performance of students based on the established SOs for the course.

The direct assessment of SOs is expected to be improved through these recommendations. With that, teaching staff are able to identify flaws in their teaching methods and subsequently improve these methods for the students.

6. Conclusions and Future Works

Conclusively, this study verified the precision of the Rasch model in evaluating the attainment of SOs for the IS223D (Object-oriented Design) course. Compared to the conventional approaches that are based on unrealistic target and process of averaging average scores, which are inaccurate and erroneous, the application of Rasch model in assessing the attainment of SOs is recommended instead. In addition, this process reveals the association pattern between students and attainment level of each SO.

The resultant outcomes of this study can assist the faculty to monitor the attainment of each SO for specific course. Furthermore, the attainment of SOs demonstrates the efficacy of teaching method as well as identifies weak students. As for future work, we will evaluate the attainment of the other remaining SOs for related courses for the continuous improvement of IS program in accordance to the requirements of ABET accreditation.

Nomenclatures

Logit	Probability of success
MEANitem	Threshold
P_r	Probability of response
$P(\theta)$	Probability of success

Greek Symbols

β	Ability of person
β_v	Ability of person *v*
δ	Difficulty of item
δ_i	Difficulty of item *i*

Abbreviations

ABET	Accreditation Board for Engineering and Technology
CLO	Course Learning Outcome
IMNSQ	Infit mean square
IS	Information Systems
OMNSQ	Outfit mean square
PIDM	Person-item distribution map
PNU	Princess Nourah bint Abdulrahman University
PTMEA CORR	Point measure correlation
SO	Student outcome
UML	Unified modeling language
ZSTD	Z-standard

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