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EXAMINING THE ADEQUACY OF AN EXIT EXAM TO MEASURE DIPLOMA STUDENTS' ACHIEVEMENT: RASCH ANALYSIS

Enas S. Abulibdeh[1*], Kamal J I Badrasawi[2], Noor Lide Abu Kassim[3]
[1*]Assistant Professor, Al Ain University, UAE; [2]Assistant Professor, International Islamic University Malaysia, Malaysia;
[3]Professor, International Islamic University Malaysia, Malaysia.
Email: [1*]enas.abulibdeh@gmail.com, [2]kamalbadrasawi@iium.edu.my, [3]noorlide@iium.edu.my

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Abstract

Purpose of the study: This paper examines the adequacy of an exit exam using the Rasch Model. It also addresses the students' achievement on the exam items according to Learning Outcomes (LOs) i.e. what LOs have been achieved and have not been achieved.

Main Findings: The Rasch analyses showed that there were issues related to the adequacy of the exit exam in terms of the items' validity and items' distribution along the interval scale. The items' qualitative investigation revealed that the stems and options of some items have problems. Overall, the exam was easy for the students, and students scored different achievement according to Learning Outcomes (LOs). These findings highlight the importance of using measurement models to validate exams as well as to provide a more accurate interpretation of students' achievement; Rasch Model is an example.

Methodology: The descriptive quantitative research design was utilized to achieve the research objectives. An exam comprises 100 Multiple choice items/questions administered to 322 students taking Professional Diploma in Teaching at a College of Education. The items cover eight 8 Learning Outcomes that students were expected to achieve when completed all the Professional Diploma courses. The collected data were analyzed using the Rasch Model for dichotomous data, and Winsteps software 4.1.0 (2018).

Applications of this study: The study provides insightful information to higher institutions in general and to colleges of education to revamp the implementation of diploma teaching programs, mainly the assessment methods.

Novelty/Originality of this study: This paper extends the evidence of providing academic staff at higher institutions with necessary information and training on measurement to come out with more informed decisions.

Keywords: *Dichotomous Data, Exit Exam, Rasch Model Analysis, Students' Abilities and Achievement.*

INTRODUCTION

Measurement and evaluation are key components of the whole teaching and learning process as they provide information related to students' learning progress or performance (Worthen, White, Fan & Sudweeks, 1999). In most academic institutions, tests are the most common instruments used to measure students' performance and then make decisions based on their test scores. Such tests have increasingly been criticized due to shortcomings in their appropriateness in terms of preparation, selection, administration, and interpretation of the results (Worthen et al., 1999). They further asserted that there should be "some structured, reliable way to measure student performance" to ensure that students are being taught effectively. In other words, examiners should use a measurement model that helps them ensure the test appropriateness and provide more accurate/reliable interpretations of the test results in a practical way. Linacre (2003) elaborated that "the more generally applicable the model, and the more useable the results, the more it is likely to meet practical needs and form the basis for scientific progress" (p. 907). This was previously highlighted by Wright (1997), who mentioned that if our decisions were based on untrustworthy measures and divergent units, then the decisions are inaccurate. For instance, using test raw scores to determine students' performance in a specific subject is not enough as they do not reflect the intended results and provide spurious or "misleading information and distortion" (Lee, 2002; Wright, 1993a; Wright, 1999; Wright & Linacre, 1997).

The Rasch Measurement Model, named after George Rasch, a Danish mathematician, helps get more accurate and reliable measurements for students' abilities or performances (Bond & Fox, 2015; Engelhard 2000; Linacre, 2003; Wright & Stone, 1979). The model is used for assessment in psychology, education, health, and physical science. In principle, it attributes the likelihood of getting an accurate answer to a particular item to the difference between person ability and item difficulty. This means that the correct answer is dominated by item difficulty and person ability. Two propositions underlie the theoretical concept of the Rasch Measurement Model (Bond & Fox, 2015). First, skilled examinees are more likely to answer all items correctly. Second, all examinees can likely answer easier items correctly. This formula shows the probabilistic dichotomous model:

$$\mathbf{P}ni\ \{x\ ni = 1\ \big|\ \mathbf{B}n\ ,\mathbf{D}i\ \} = \exp\ (\ \mathbf{B}n\text{-}\mathbf{D}i\ )\ /\ [\ 1+\exp\ (\ \mathbf{B}n\text{-}\mathbf{D}i)\ ]$$

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Where:

P*ni* {x *ni* = 1 ⎪**B***n* ,**D***i* }is the probability of person on item (*i*) scoring a correct response (x =1) rather than an incorrect response (x = 0) , given person ability **B***n* and item difficulty (**D***i*). This probability is equal to the constant e, or natural log function (2.7183) raised to the difference between a person's ability and item's function (Bn-**D**i), divided by 1 plus this same value (Bond & Fox, 2015).

Among the uses of the Rasch Measurement Model are to validate tests, ensure test equivalence using common item equating i.e. make sure that the tests are comparable if different tests are used every year, and display students' levels of ability and items difficulty on a same interval scale. Boone (2016) pointed out that Rasch analysis is a psychometric technique used to ensure the precision that researchers need to "construct instruments, monitor instrument quality, and compute respondents' performances" (p.1). The same ideas were earlier iterated in (Curtis & Boman, 2007; Ingebo, 1997; Kimberlin & Winterstein; 2008). Therefore, this paper addresses the adequacy of an exit exam using the Rasch Measurement Model (RMM). Particularly, the analysis presents the (1) validity of test items, (2) construct validity, (3) capacity of the test to produce results that are consistent with the purpose of the measurement, and (4) validity of student responses. It also shows all the students' achievement on the exam items according to Learning Outcomes (LOs) i.e. what LOs have been achieved and have not been achieved. The Rasch analysis was conducted using Winsteps statistical software, version 4.1.0 (Linacre, 2018).

RESEARCH METHOD

This is quantitative research utilized the descriptive approach that is often used to describe data and characteristics related to issues being investigated in research using certain instruments such as questionnaires, tests, self-reports, observations, etc. (Creswell, 2014; Gay & Airasian, 2012). In this research, an exam instrument was used to assess the students' achievement in the courses they had taken in a professional diploma in Teaching at a College of Education. This exam is usually conducted at the end of the Teaching Diploma program for the students who complete all the program courses. The exam consisted of one hundred (100) MCQ items meant to assess eight (8) Learning Outcomes (LOs) according to the courses taught to the students. More specifically, it included 14 items for the learning outcome "*Plan and design an effective student-centered learning environment* (**PD**); 13 items for "*Demonstrate knowledge of content and pedagogy necessary for effective instruction in their field of study* (**KCM)**"; 13 items for "*Demonstrate knowledge of their students' characteristics* (**KCH**)"; 13 items for "*Apply a research-utilized multi-methodology approach and make any necessary changes or adaptations of their teaching strategies based upon an ongoing assessment process* (**APP**)"; 14 items for "*Develop constructive communication skills with their students, parents, school administrators, and colleagues to solve problems and enhance students' learning* (**DCOM**)"; 13 items for "*Conduct an ongoing assessment/evaluation of student learning.* (**EV**)"; 10 items for "*Use or Apply information and communication technology tools in instructional planning, delivery of instruction, and in the assessment of students' learning* (**TECH**)"; and 10 items for "*Demonstrate professional responsibility towards their students, school and society* (**PR**)". It is worthwhile to add the exam content validity would not be an issue because content experts/lecturers usually construct the items of this type of exam. Meanwhile, the measurement requirements of the exam were thoroughly explained in the discussion section as one of the research objectives was to address the adequacy of the test using the Rasch Model and Winsteps software, version 4.1.0. (2018). It discusses the validity of exam items, constructs validity, the capacity of the exam to produce results that are consistent with the purpose of the measurement and validity of student responses. Three hundred and twenty students (320) of Professional Diploma in Teaching at a College of Education answered the exam items, and all of them were included in the Rasch Model final analysis. All the results were presented in Tables and Figures.

RESULTS AND DISCUSSION

Adequacy of Exit Exam

The following analyses show the validity of exam items, construct validity, the capacity of the exam to produce results that are consistent with the purpose of the measurement, and the validity of student responses.

For the exam items validity, three indicators were used Item polarity, Item Fit, and Unidimensionality. Item polarity indicates to what extent all the items in a given test are in the same direction to measure the measured construct. Negative or zero value items mean that the answers to these items are in conflict with the other items included in the test. Therefore, items with high positive values (0.3-0.8) are desired (Linacre, 2019). Items below 0.3 show that items are not discriminating against the examinees effectively. Table A1 shows the point measure correlation (PTMEA CORR.) for the 100 items. The results indicate that three items (App 43, PR 98, and DCOM59) had negative point measure correlation coefficients (-.12, -.07, and -.02) respectively. This means that the items were not defining the measured construct in the same direction as other items. There is another possibility that the examinees are not responding to these items as the model expected because these items were very difficult or there were issues about the items construction and the options. Deleting the unexpected

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responses (with the Outfit MNSQ) above 1.3 did not improve the correlation coefficients. However, the qualitative investigation for the three items referred to certain issues (related either to items' stems or their options). For example, item APP 43 might have more than one possible answer; and the same has happened to item DCOM 98; whereas item PR 98 has no possible correct answer. This is supported by the item difficulty measures and item category options frequencies (percentages) (Appendix A1). All other items had positive point measure correlation coefficients, but the majority were below 0.3 (between $0.01 \leq 0.30$). These three items and items with low point measure correlation coefficients, < 0.20 were plotted with items that had correlation coefficients ≥ 0.20. Figure 1 shows all the items were between the interval lines, indicating that all the items were in the same direction in measuring the same construct.

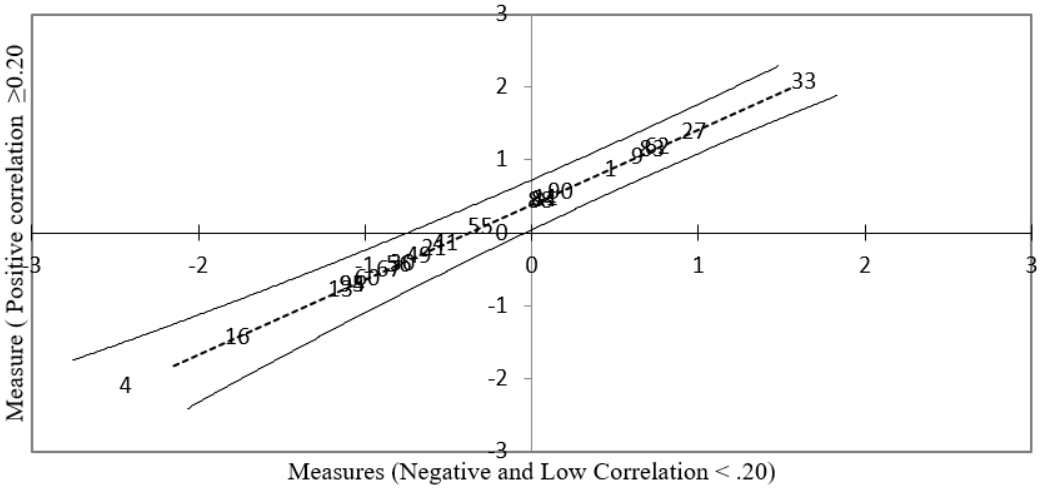

Figure 1: Cross Plot: Item Measures Based on Item Correlations

Fit statistics are investigated to ensure the items are contributing meaningfully to the measured construct. The two major fit statistics (the infit and outfit Mean-square statistics) were used (Bond & Fox, 2015; Boone, 2016; Green & Frantom, 2002). The recommended range for multiple-choice items is (0.7-1.3) (Bond & Fox, 2015). Table A1 shows the infit and outfit mean square of individual items. All items were within the recommended infit and outfit mean-square range (0.7 - 1.3), except two items (PR 98 and APP 43) with Outfit mean square above 1.3. The two items had issues in their writing as discussed earlier. The mean score for the infit mean square was (1.00 logit) while it was (.99 logit) for the Outfit mean square, almost the expected value of (1.00 logit). However, the standard error measurement for the individual items ranged between (.12-.32), indicating that some items might not function effectively (See Appendix A1).

Unidimensionality is used to denote that the items of a given test measure a single unidimensional construct, and it is measured by using the principal component analysis of residuals. Table A1 demonstrates that Unidimensionality is supported. However, the raw variance explained measure was low (25.7%). There is no secondary dimension since all the factors in the first and second contrasts were less than 5%. Moreover, the largest factor extracted from the residuals was equivalent to 2.67.

The reliability of the difficulty of the items was quite high at (0.99) as seen in Table A1, which indicates the possibility to replicate the ordering of item difficulty with similar groups of students. The item separation index was 8.34, indicating that the items can be divided into at least 8 difficulty levels, which is satisfactory for 100 items. However, the distribution of the items on the map showed that there were two gaps at the end and bottom parts of the scale. In addition, some clusters of items appeared in the middle (Figure 2). The qualitative investigation showed that there were issues with items that made the majority of students not to get the correct answers. Table 1 also shows that the reliability of the examinees' ability measure was not high (0.77), which suggests that the likelihood of replicating the students ordering with other items of the same difficulty would not be high. The examinees' separation index was 1.85, showing that the examinees could be split into two levels of ability. The results showed that in general examinees were not answering as the model expected, supported by the high value (.24) for the measurement standard error (Figure 3).

Table 1: Item statistics of 100 Exam Items

Item Entry	Difficulty measures	S.E	Infit MNSQ	Outfit MNSQ	PT-M CORR	Item Entry	Difficulty measures	S.E	Infit MNSQ	Outfit MNSQ	PT-M CORR
PD1	1.08	0.12	1.07	1.09	0.09	DCOM54	0.02	0.12	0.99	1.01	0.24
PD2	-0.31	0.13	1.07	1.14	0.07	DCOM55	-0.12	0.12	1.08	1.14	0.06

PD3	1.39	0.12	1.06	1.09	0.10	DCOM56	-1.44	0.18	1.01	1.08	0.14
PD4	1.47	0.12	1.05	1.10	0.11	DCOM57	0.02	0.12	0.97	0.96	0.30
PD5	-0.7	0.14	0.97	0.96	0.27	DCOM58	0.82	0.12	0.98	0.97	0.29
PD6	-0.6	0.14	0.99	0.97	0.24	DCOM59	1.86	0.13	1.10	1.20	-0.02
PD7	0.14	0.12	0.97	0.97	0.29	DCOM60	-1.79	0.20	1.01	1.09	0.11
PD8	-0.23	0.13	0.95	0.93	0.33	DCOM61	-0.25	0.13	1.03	1.02	0.18
PD9	-0.49	0.13	1.06	1.07	0.10	DCOM62	0.47	0.12	1.03	1.03	0.19
PD10	0.12	0.12	0.98	0.98	0.27	DCOM63	-1.67	0.19	0.93	0.76	0.34
PD11	-0.9	0.15	1.00	1.03	0.19	DCOM64	-1.57	0.18	0.99	0.95	0.20
PD12	0.53	0.12	0.98	0.98	0.27	DCOM65	-1.18	0.16	0.94	0.96	0.29
PD13	2.18	0.14	1.01	1.12	0.13	DCOM66	2.34	0.15	0.95	0.92	0.28
PD14	0.69	0.11	0.97	0.97	0.29	DCOM67	0.48	0.12	1.03	1.04	0.18
KCM15	-2.33	0.25	0.95	0.63	0.31	EV68	-0.53	0.13	0.95	0.89	0.34
KCM16	0.17	0.12	1.03	1.05	0.18	EV69	-2.90	0.32	0.95	0.56	0.29
KCM17	-0.9	0.15	0.97	1.00	0.24	EV70	1.68	0.13	1.03	1.08	0.13
KCM18	0.05	0.12	1.03	1.06	0.17	EV71	-0.74	0.14	0.95	0.89	0.33
KCM19	-0.99	0.15	0.99	0.97	0.22	EV72	0.07	0.12	1.07	1.07	0.11
KCM20	-1.06	0.15	0.9	0.77	0.42	EV73	-0.33	0.13	0.99	0.99	0.24
KCM21	0.74	0.11	1.03	1.03	0.18	EV74	0.36	0.12	0.97	0.96	0.30
KCM22	0.78	0.11	0.97	0.97	0.29	EV75	-2.05	0.22	0.95	0.88	0.24
KCM23	-0.44	0.13	0.95	0.92	0.32	EV76	1.49	0.12	0.96	0.95	0.30
KCM24	-0.72	0.14	0.96	0.90	0.30	EV77	-0.64	0.14	1.00	0.97	0.23
KCM25	1.68	0.13	0.99	0.98	0.24	EV78	-0.12	0.12	0.97	0.98	0.29
KCM26	0.24	0.12	0.99	0.97	0.27	EV79	1.63	0.13	1.05	1.09	0.11
KCM27	1.06	0.12	1.03	1.04	0.17	EV80	0.02	0.12	0.92	0 .90	0.40
KCH28	0.61	0.11	1.05	1.05	0.15	TECH81	-1.29	0.17	0.94	0.88	0.30
KCH29	-0.99	0.15	0.97	0.93	0.26	TECH82	-1.91	0.21	0.93	0.74	0.33
KCH30	1.86	0.13	1.09	1.19	0.01	TECH83	-1.11	0.16	1.01	1.11	0.13
KCH31	1.02	0.12	1.01	0.01	0.22	TECH84	2.38	0.15	1.05	1.21	0.03
KCH32	-1.67	0.19	0.98	0.92	0.20	TECH85	1.00	0.12	1.08	1.11	0.08
KCH33	-1.29	0.17	1.02	1.05	0.14	TECH86	-0.51	0.13	0.97	0.92	0.29
KCH34	-0.78	0.14	0.96	0.93	0.29	TECH87	0.12	0.12	0.98	0.97	0.28
KCH35	-0.51	0.13	0.95	0.96	0.31	TECH88	0.19	0.12	1.09	1.10	0.07
KCH36	0.15	0.12	0.99	0.99	0.25	TECH89	0.51	0.12	0.99	0.99	0.26
KCH37	0.81	0.12	1.00	1.00	0.24	TECH90	0.76	0.11	1.05	1.06	0.14
KCH38	-0.53	0.13	0.97	0.97	0.27	PR91	0.85	0.12	1.12	1.13	0.01
KCH39	-1.16	0.16	0.95	0.88	0.29	PR92	-0.14	0.12	1.00	1.01	0.22
KCH40	1.24	0.12	0.99	1.00	0.24	PR93	1.64	0.13	0.98	1.00	0.25
App41	-0.99	0.15	1.01	1.12	0.13	PR94	3.09	0.2	1.01	1.03	0.12
App42	-0.70	0.14	0.97	0.94	0.27	PR95	-2.27	0.24	0.99	0.93	0.15
App43	2.66	0.17	1.09	1.49	-0.12	PR96	-2.47	0.27	0.93	0.67	0.31
App44	-0.58	0.14	1.00	0.94	0.24	PR97	0.32	0.12	0.94	0.92	0.37
App45	-0.97	0.15	0.96	0.97	0.27	PR98	3.56	0.24	1.04	1.50	-0.07
App46	-0.12	0.12	0.97	0.95	0.29	PR99	0.29	0.12	1.05	1.05	0.15
App47	0.1	0.12	0.99	0.97	0.27	PR100	0.33	0.12	0.94	0.93	0.35
App48	-0.55	0.13	0.97	0.94	0.28	Means	0.00	0.14	1.00	0.99	
App49	-0.33	0.13	1.10	1.14	0.02	**Item Reliability**				0.99	
App50	-1.41	0.17	0.98	0.93	0.22	**Item separation**				8.34	
App51	-1.32	0.17	0.94	0.83	0.32	**Person Reliability**				0.77	
App52	-0.38	0.13	0.95	0.92	0.33	**Person Separation**				1.85	
App53	1.86	0.13	0.96	0.93	0.28	**Raw variance explained by measures**				25.7%	
Continue Entry Number						**Unexplained variance in 1st contrast**				2.67	

For the construct validity, the scale continuum of increasing intensity was examined. When the items are distributed evenly and there are no significant gaps between the items distribution, the continuum of increasing intensity is achieved. Figure 2

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shows that visible gaps between items distribution were not significant. However, the upper and lower ends of the scale showed two wide gaps, indicating that the most difficult items are at the top and the easiest ones are at the bottom. Most of the items were accumulated around the mean (i.e. in the middle of the scale). This supports that either the items were not discriminating the examinees effectively, or the examinees were with narrow ability range. Qualitative investigations showed that the most difficult items placed at the upper part of the scale had issues in the stem and the options, which made the majority of students, not get the correct answers. The clustered items in the middle should be investigated to see if they were measuring almost the same things. Figure 2 clearly shows the item difficulty measures ordered from the most difficult items (PR 98 (3.56 logit) PR 94 (3.09 logit) to the easiest items (EV69 (-2.90 logit) and PR96 (-2.47 logit).

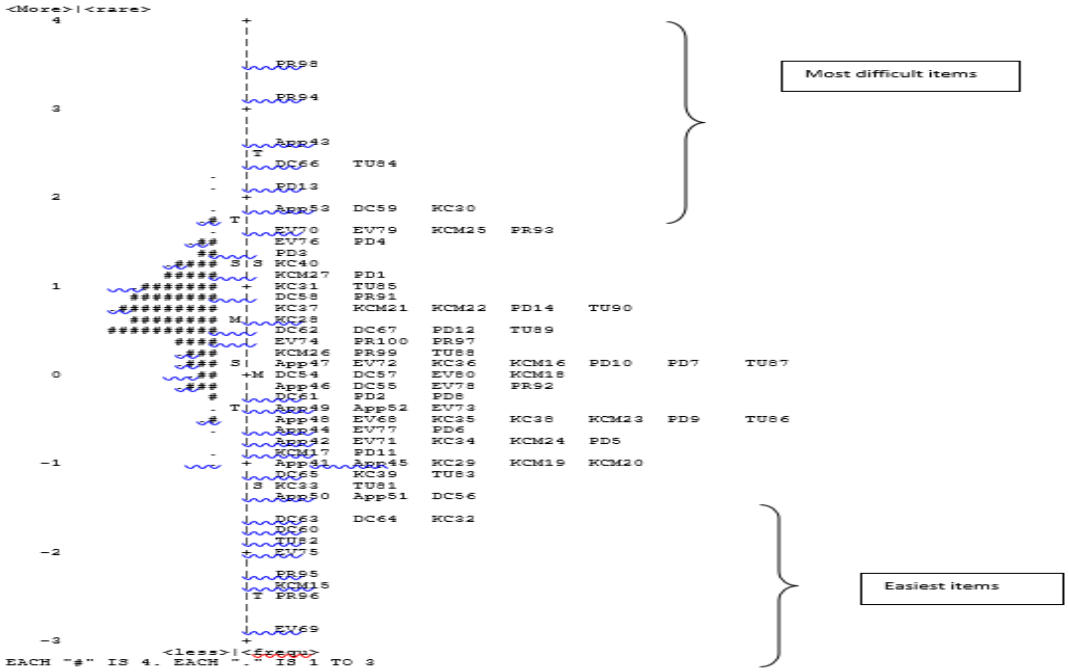

Figure 2: Item-Map

The table in appendix A2 shows the fit statistics of the examinee responses. The infit MNSQ value was 1.00 logit, the expected value of the model (1.00). The Outfit MNSQ (0.99) was close to the value expected by the model. However, the standard error was (0.24 logits). Eight students were to be found misfit as their Outfit MNSQ was above the recommended range (.7-1.3). It seems that students were not responding to items as Rasch Model expected, as depicted in Figure 3. One proposed reason for the high misfit statistics is lucky guessing by low achievers and the issues found in some items' options and stems.

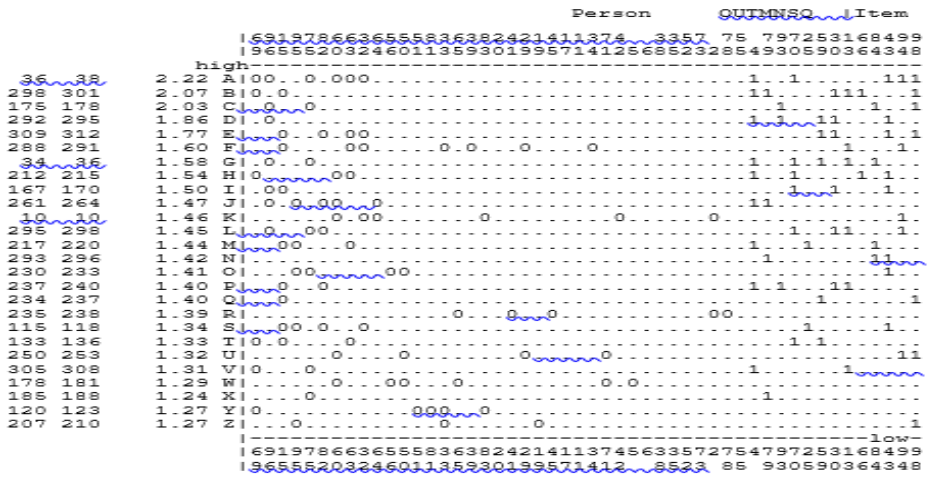

Figure 3: Most Mis-fitting Response Strings

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In general, the results showed that the test might not be adequate to be used to describe the examinees' achievement. There are good items while many others need further qualitative investigation.

STUDENTS' ACHIEVEMENT LEVELS

The Rasch analyses were conducted to determine the students' achievement levels on the exam items as overall and according to each learning outcome that students were expected to achieve once they completed the courses taught in the professional Diploma in Teaching at a College of Education. Rasch Item and Person Maps can display the positions of Items and Persons on the same interval scales. They help to ensure which learning outcomes have been achieved and yet have not been achieved. In other words, they help to determine how much students have acquired from the courses taken in the program, and in which learning outcomes they showed higher and lower achievement. The Maps can also show the most able students placed at the upper part of the scale and the least able students placed toward the lower part of the scale.

On average, the students' ability as a group was higher than the item difficulty. The students found the exam as easy because the mean score of their ability was 0.67 logit, which is considered quite larger than the mean score of the item difficulty (0.0) (Figure 4). The map shows that items that were correctly answered by the examinees are placed towards the lower part of the scale, while the least correctly answered, are positioned towards the upper part. Moreover, the examinee ability measures spanned about 3.19 logits (from -.99 to + 2.20) while item difficulty measures spread was about 6.46 logits (from -2.9 to + 3.56). Figure 4 also shows that most students were distributed between -.5 logit and +1 logit, and most of the students are accumulated around the middle of the scale, which means that they almost have a narrow range of ability.

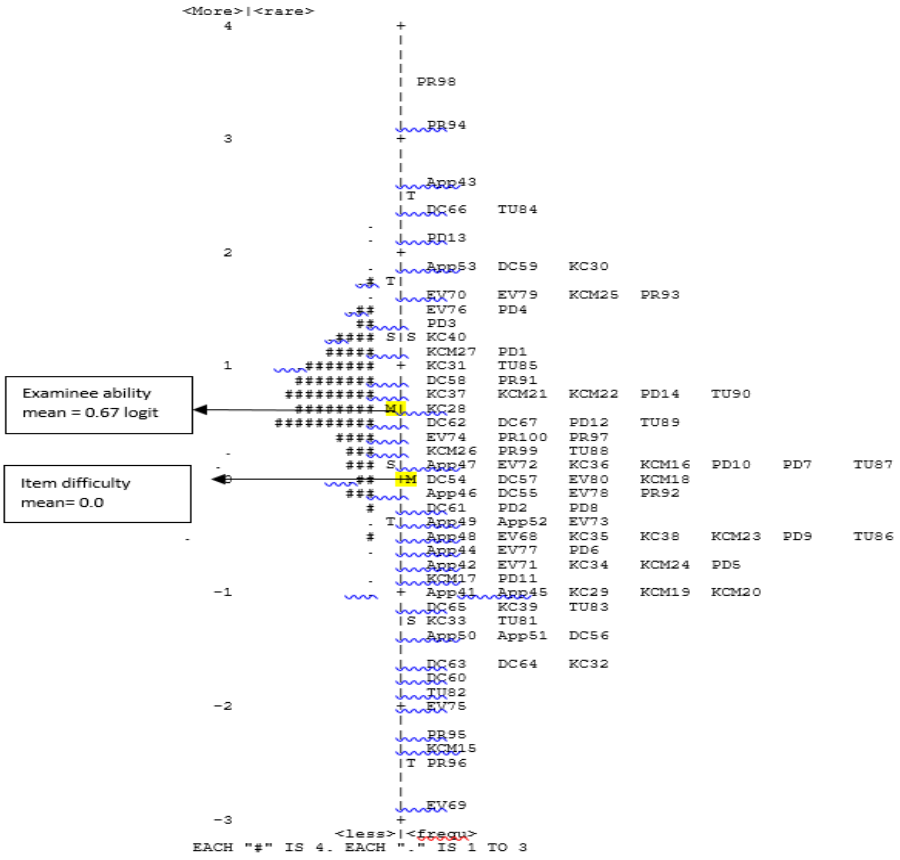

Figure 4: Examinee Ability and Item Difficulty Map

Though in overall it was easy for the students to answer the exam items, it is essential to highlight that students scored different levels according to the learning outcomes that students were expected to achieve when they had finished all the diploma courses. Figure 5 shows the means of each learning outcome items and the distribution and the hierarchical order of items. The most difficult learning outcome for students was "*Demonstrate professional responsibility towards their students, school, and society"* (**PR***)* (M = 0.52 logits). It is followed by the learning outcome *"Plan and design an effective student-centered learning environment"* (**PD***)* (M = 0.31 logits), and *"Use or Apply information and communication technology tools in instructional planning, delivery of instruction, and in the assessment of students' learning* (**TECH***)"* (M = 0.01). Whereas

the easiest category was related to the learning outcome, *"Apply a research-utilized multi-methodology approach and make any necessary changes or adaptations of their teaching strategies based upon an ongoing assessment process"* **(APP)** (M = -0.21 logits). It is followed by *"Conduct an ongoing assessment/evaluation of student learning"* **(EV)** (M = -0.16 logits), "*Develop constructive communication skills with their students, parents, school administrators, and colleagues to solve problems and enhance students' learning" (**DCOM**)* (M = -0.14 logits), "*Demonstrate knowledge of content and pedagogy necessary for effective instruction in their field of study* (**KCM**)(m= -0.13 logits), and *Demonstrate knowledge of their students' characteristics "*(**KCH**) (M = -0.10). However, the items of each learning outcome showed different distributions. Some items were placed at the top while others were placed either in the middle or at the bottom of the measurement scale. Meaning that the students had or had not achieved certain skills under each learning outcome. The students were not able to answer the questions placed at the top correctly, while it was easy for them to answer the question at the bottom correctly as displayed in Figure 5.

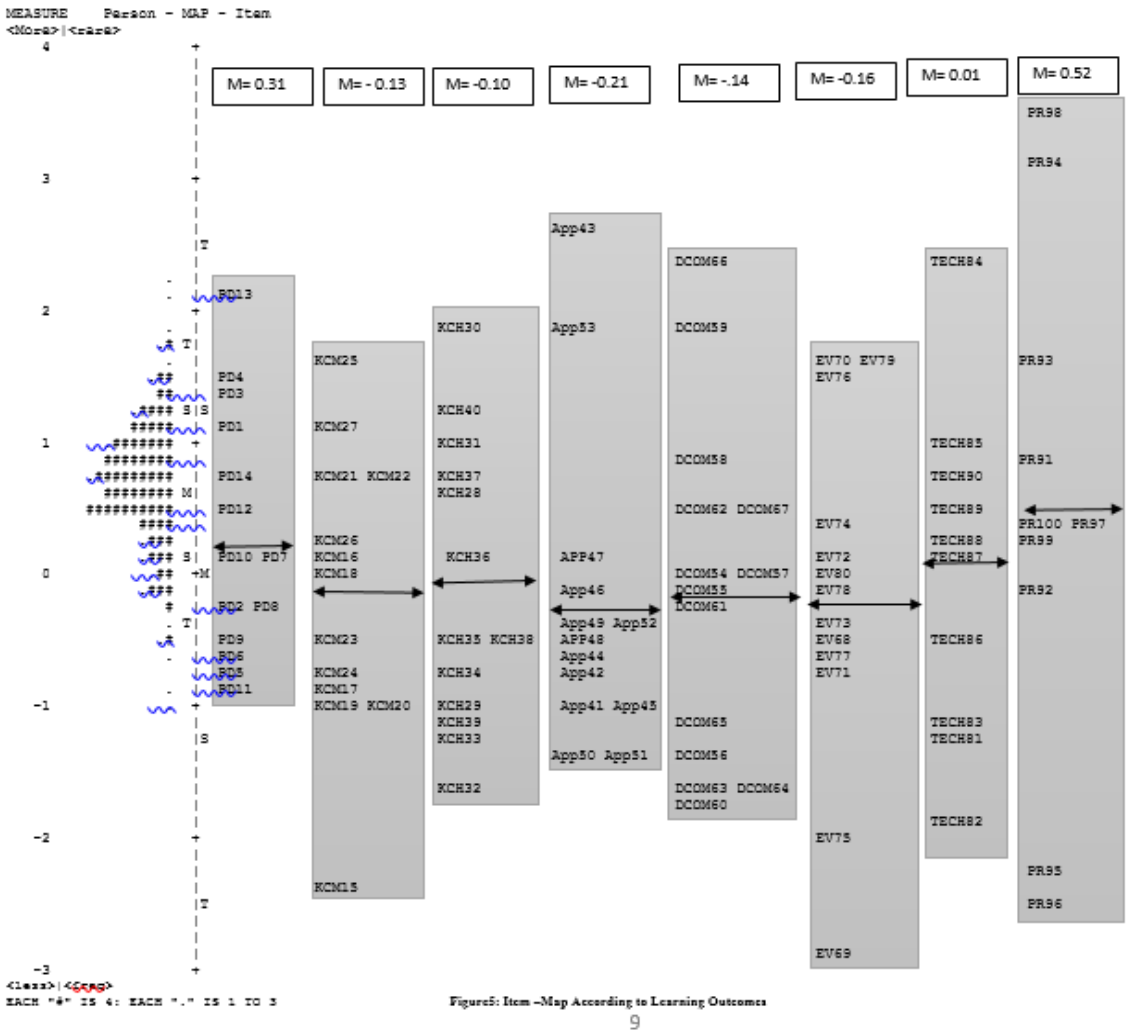

Figure 5: Item –Map According to Learning Outcomes

CONCLUSION

The Rasch analyses showed that there were few issues related to the adequacy of the exit exam in terms of the items' validity and items' distribution along the interval scale. The items' qualitative investigation revealed that the stems and options of some items have problems. Overall, the students found the exam easy, and the results showed that the mean person ability (0.67 logit) was greater than the item mean (0.0 logit). However, the majority of the students were gathered in the middle of the scale showing that students might have a narrow range of ability. Students scored different achievement according to the learning outcomes which they were expected to achieve once they completed the courses of the professional Diploma in Education. This means that they would graduate without mastering certain skills. In principle, the analysis showed a need of a measurement model to validate the items and show how much students have achieved during their study.

LIMITATION AND STUDY FORWARD

It is recommended that the existing items should be empirically examined before given to students to ensure the requirements of an accurate measurement, and academic staff and exam writers should be given sufficient training or guidelines on how to prepare and construct accurate and appropriate measurements. The Rasch maps could help the college to see what students can and cannot do because the maps display students and items on the same interval scale. Some of the good items could be added to other coming exit exams to conduct further analysis that ensures comparable exams have obtained as recommended by (Wright, 1993b). This research has its own limitations. The research only focused on the adequacy of the exit exam and students' achievement using the Rasch Model. However, the research did not determine which groups of students performed high or low in the exam. The research did not also examine the factors that might affect students' performance on the exam items such as items format, allocated time, and the number of items.

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AUTHORS' CONTRIBUTION

The main Author, Dr. Enas Said Abulibdeh, dealt with the conceptual design, data collection, and preparation of the manuscript. Data analysis, interpretation, and presentation of reports, preparation of the manuscript, and preparation of the final draft have been done by Dr. Kamal J I Badrasawi. Data analysis, interpretation, and presentation of reports and preparation of the final draft have been done by Prof. Noor Lide.

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Appendix A1: Item statistics: Entry order

ENTRY NUMBER	TOTAL SCORE	TOTAL COUNT	MEASURE	MODEL S.E.	INFIT MNSQ	INFIT ZSTD	OUTFIT MNSQ	OUTFIT ZSTD	PTMEASUR-AL CORR.	PTMEASUR-AL EXP.	EXACT MATCH OBS%	EXACT MATCH EXP%	Item
1	131	322	1.08	.12	1.07	2.3	1.09	2.4	.09	.24	61.2	62.1	PD1
2	231	322	-.31	.13	1.07	1.2	1.14	2.1	.07	.23	73.0	72.3	PD2
3	109	322	1.39	.12	1.06	1.5	1.09	1.6	.10	.23	64.0	67.1	PD3
4	103	322	1.47	.12	1.05	1.1	1.10	1.8	.11	.22	69.6	68.6	PD4
5	253	322	-.70	.14	.97	-.3	.96	-.4	.27	.21	78.3	78.6	PD5
6	248	322	-.60	.14	.99	-.1	.97	-.3	.24	.22	77.6	77.1	PD6
7	201	322	.14	.12	.97	-.8	.97	-.8	.29	.24	68.6	64.8	PD7
8	226	322	-.23	.13	.95	-.9	.93	-1.2	.33	.23	71.4	70.9	PD8
9	242	322	-.49	.13	1.06	1.0	1.07	.9	.10	.22	74.5	75.4	PD9
10	202	322	.12	.12	.98	-.5	.98	-.3	.27	.24	67.4	65.0	PD10
11	263	322	-.90	.15	1.00	.0	1.03	.3	.19	.20	81.4	81.7	PD11
12	172	322	.53	.12	.98	-.6	.98	-.7	.27	.24	59.9	60.1	PD12
13	62	322	2.18	.14	1.01	.2	1.12	1.2	.13	.19	81.1	80.7	PD13
14	160	322	.69	.11	.97	-1.1	.97	-.8	.29	.24	62.7	59.4	PD14
15	305	322	-2.33	.25	.95	-.2	.63	-1.6	.31	.12	94.7	94.7	KCM15
16	199	322	.17	.12	1.03	.8	1.05	1.1	.18	.24	64.3	64.4	KCM16
17	263	322	-.90	.15	.97	-.3	1.00	.1	.24	.20	82.0	81.7	KCM17
18	207	322	.05	.12	1.03	.8	1.06	1.2	.17	.24	65.5	66.1	KCM18
19	267	322	-.99	.15	.99	-.1	.97	-.2	.22	.20	83.2	82.9	KCM19
20	270	322	-1.06	.15	.90	-1.0	.77	-2.1	.42	.19	83.9	83.8	KCM20
21	156	322	.74	.11	1.03	1.1	1.03	1.1	.18	.24	56.8	59.4	KCM21
22	153	322	.78	.11	.97	-1.0	.97	-.9	.29	.24	62.1	59.5	KCM22
23	239	322	-.44	.13	.95	-.7	.92	-1.1	.32	.22	74.5	74.6	KCM23
24	254	322	-.72	.14	.96	-.5	.90	-1.0	.30	.21	79.2	78.9	KCM24
25	90	322	1.68	.13	.99	-.2	.98	-.3	.24	.21	71.1	72.2	KCM25
26	194	322	.24	.12	.99	-.4	.97	-.8	.27	.24	62.7	63.4	KCM26
27	132	322	1.06	.12	1.03	1.1	1.04	1.2	.17	.24	60.6	61.9	KCM27
28	166	322	.61	.11	1.05	1.8	1.05	1.6	.15	.24	54.0	59.6	KCH28
29	267	322	-.99	.15	.97	-.3	.93	-.5	.26	.20	83.2	82.9	KCH29
30	79	322	1.86	.13	1.09	1.3	1.19	2.2	.01	.21	74.8	75.5	KCH30
31	135	322	1.02	.12	1.01	.3	1.01	.2	.22	.24	63.4	61.4	KCH31
32	291	322	-1.67	.19	.98	-.1	.92	-.4	.20	.16	90.4	90.4	KCH32
33	279	322	-1.29	.17	1.02	.2	1.05	.4	.14	.18	86.6	86.6	KCH33
34	257	322	-.78	.14	.96	-.4	.93	-.7	.29	.21	80.7	79.8	KCH34
35	243	322	-.51	.13	.95	-.8	.96	-.4	.31	.22	77.0	75.7	KCH35
36	200	322	.15	.12	.99	-.1	.99	-.1	.25	.24	66.5	64.6	KCH36
37	151	322	.81	.12	1.00	.2	1.00	-.1	.24	.24	56.5	59.6	KCH37
38	244	322	-.53	.13	.97	-.3	.97	-.3	.27	.22	75.5	76.0	KCH38
39	274	322	-1.16	.16	.95	-.4	.88	-1.0	.29	.19	85.1	85.1	KCH39
40	119	322	1.24	.12	.99	-.1	1.00	.0	.24	.23	66.8	64.6	KCH40
41	267	322	-.99	.15	1.01	.2	1.12	1.0	.13	.20	83.2	82.9	App41
42	253	322	-.70	.14	.97	-.3	.94	-.6	.27	.21	78.9	78.6	App42
43	42	322	2.66	.17	1.09	.8	1.49	3.0	-.12	.16	87.0	86.9	App43
44	247	322	-.58	.14	1.00	.0	.94	-.7	.24	.22	75.5	76.9	App44
45	266	322	-.97	.15	.96	-.4	.97	-.2	.27	.20	82.9	82.6	App45
46	219	322	-.12	.12	.97	-.6	.95	-.8	.29	.23	68.9	69.0	App46
47	204	322	.10	.12	.99	-.2	.97	-.7	.27	.24	63.0	65.5	App47
48	245	322	-.55	.13	.97	-.3	.94	-.7	.28	.22	77.0	76.3	App48
49	232	322	-.33	.13	1.10	1.7	1.14	2.0	.02	.23	68.9	72.6	App49
50	283	322	-1.41	.17	.98	-.1	.93	-.4	.22	.17	87.9	87.9	App50
51	280	322	-1.32	.17	.94	-.5	.83	-1.2	.32	.18	87.0	86.9	App51
52	235	322	-.38	.13	.95	-.9	.92	-1.1	.33	.22	74.5	73.4	App52
53	79	322	1.86	.13	.96	-.5	.93	-.9	.28	.21	75.5	75.5	App53
54	209	322	.02	.12	.99	-.2	1.01	.3	.24	.24	68.0	66.6	DCOM54
55	219	322	-.12	.12	1.08	1.7	1.14	2.3	.06	.23	68.3	69.0	DCOM55
56	284	322	-1.44	.18	1.01	.1	1.08	.6	.14	.17	88.2	88.2	DCOM56
57	209	322	.02	.12	.97	-.7	.96	-.9	.30	.24	66.8	66.6	DCOM57
58	150	322	.82	.12	.98	-.9	.97	-1.0	.29	.24	59.3	59.7	DCOM58
59	79	322	1.86	.13	1.10	1.6	1.20	2.4	-.02	.21	74.8	75.5	DCOM59
60	294	322	-1.79	.20	1.01	.1	1.09	.5	.11	.15	91.3	91.3	DCOM60
61	227	322	-.25	.13	1.03	.6	1.02	.4	.18	.23	69.9	71.2	DCOM61
62	177	322	.47	.12	1.03	.9	1.03	1.0	.19	.24	58.1	60.6	DCOM62
63	291	322	-1.67	.19	.93	-.4	.76	-1.4	.34	.16	90.4	90.4	DCOM63
64	288	322	-1.57	.18	.99	.0	.95	-.2	.20	.16	89.4	89.4	DCOM64
65	275	322	-1.18	.16	.94	-.5	.96	-.3	.29	.19	85.4	85.4	DCOM65
66	55	322	2.34	.15	.95	-.5	.92	-.7	.28	.18	82.9	82.9	DCOM66
67	176	322	.48	.12	1.03	1.1	1.04	1.2	.18	.24	59.0	60.5	DCOM67
68	244	322	-.53	.13	.95	-.8	.89	-1.3	.34	.22	76.1	76.0	EV68
69	312	322	-2.90	.32	.95	-.1	.56	-1.4	.29	.10	96.9	96.9	EV69
70	90	322	1.68	.13	1.03	.6	1.08	1.2	.13	.21	73.0	72.2	EV70
71	255	322	-.74	.14	.95	-.7	.89	-1.2	.33	.21	79.5	79.2	EV71
72	206	322	.07	.12	1.07	1.6	1.07	1.5	.11	.24	64.0	65.9	EV72
73	232	322	-.33	.13	.99	-.1	.99	-.1	.24	.23	72.7	72.6	EV73
74	185	322	.36	.12	.97	-.9	.96	-1.1	.30	.24	61.2	61.8	EV74
75	300	322	-2.05	.22	.95	-.2	.88	-.5	.24	.14	93.2	93.2	EV75
76	102	322	1.49	.12	.96	-.9	.95	-.8	.30	.22	71.7	68.9	EV76

77	250	322	-.64	.14	1.00	.0	.97	-.3	.23	.21	77.3	77.7	EV77
78	219	322	-.12	.12	.97	-.7	.98	-.4	.29	.23	70.8	69.0	EV78
79	93	322	1.63	.13	1.05	.9	1.09	1.3	.11	.22	70.8	71.4	EV79
80	209	322	.02	.12	.92	-2.0	.90	-2.2	.40	.24	70.5	66.6	EV80
81	279	322	-1.29	.17	.94	-.5	.88	-.8	.30	.18	86.6	86.6	TECH81
82	297	322	-1.91	.21	.93	-.4	.74	-1.3	.33	.15	92.2	92.2	TECH82
83	272	322	-1.11	.16	1.01	.1	1.11	.9	.13	.19	84.5	84.5	TECH83
84	53	322	2.38	.15	1.05	.6	1.21	1.7	.03	.18	83.5	83.5	TECH84
85	137	322	1.00	.12	1.08	2.5	1.11	3.0	.08	.24	57.8	61.1	TECH85
86	243	322	-.51	.13	.97	-.5	.92	-.9	.29	.22	76.4	75.7	TECH86
87	202	322	.12	.12	.98	-.5	.97	-.6	.28	.24	64.9	65.0	TECH87
88	197	322	.19	.12	1.09	2.4	1.10	2.4	.07	.24	59.0	64.0	TECH88
89	174	322	.51	.12	.99	-.3	.99	-.4	.26	.24	59.3	60.3	TECH89
90	155	322	.76	.11	1.05	1.9	1.06	1.9	.14	.24	55.3	59.5	TECH90
91	148	322	.85	.12	1.12	4.4	1.13	3.9	.01	.24	49.7	59.8	PR91
92	220	322	-.14	.12	1.00	.1	1.01	.2	.22	.23	69.3	69.3	PR92
93	92	322	1.64	.13	.98	-.3	1.00	.0	.25	.22	71.7	71.7	PR93
94	29	322	3.09	.20	1.01	.1	1.03	.2	.12	.14	91.0	91.0	PR94
95	304	322	-2.27	.24	.99	.0	.93	-.2	.15	.13	94.4	94.4	PR95
96	307	322	-2.47	.27	.93	-.2	.67	-1.3	.31	.12	95.3	95.3	PR96
97	188	322	.32	.12	.94	-2.0	.92	-2.2	.37	.24	65.8	62.3	PR97
98	19	322	3.56	.24	1.04	.3	1.50	1.9	-.07	.11	94.1	94.1	PR98
99	190	322	.29	.12	1.05	1.4	1.05	1.4	.15	.24	60.2	62.6	PR99
100	187	322	.33	.12	.94	-1.8	.93	-1.9	.35	.24	63.7	62.1	PR100
MEAN	202.1	322.0	.00	.14	1.00	.1	.99	.1			74.1	74.3	
P.SD	72.9	.0	1.25	.04	.05	1.0	.13	1.3			11.2	10.7	

Appendix A2: Person Statistics: Misfit 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%	Person
36	47	100	-.18	.23	1.34	3.4	2.22	5.8	A .15	.47	65.0	70.2	38
298	44	100	-.34	.23	1.34	3.5	2.07	5.1	B .16	.46	61.0	70.4	301
175	40	100	-.55	.23	1.31	3.1	2.03	4.5	C .19	.46	65.0	70.9	178
292	32	100	-.99	.24	1.27	2.4	1.86	3.1	D .19	.43	67.0	73.9	295
309	47	100	-.18	.23	1.23	2.4	1.77	4.1	E .26	.47	67.0	70.2	312
288	64	100	.72	.24	1.31	2.7	1.60	2.9	F .23	.48	67.0	73.9	291
34	38	100	-.66	.23	1.21	2.1	1.58	2.7	G .26	.45	68.0	71.5	36
212	46	100	-.24	.23	1.23	2.4	1.54	2.9	H .27	.47	65.0	70.2	215
167	38	100	-.66	.23	1.22	2.2	1.50	2.4	I .27	.45	62.0	71.5	170
261	50	100	-.03	.23	1.34	3.4	1.47	2.7	J .22	.47	58.0	70.2	264
10	72	100	1.20	.25	1.19	1.5	1.46	1.9	K .30	.46	75.0	77.9	10
295	52	100	.08	.23	1.17	1.8	1.45	2.6	L .32	.47	67.0	70.3	298
217	51	100	.02	.23	1.31	3.2	1.44	2.6	M .24	.47	57.0	70.2	220
293	41	100	-.50	.23	1.15	1.6	1.42	2.2	N .33	.46	65.0	70.7	296
230	51	100	.02	.23	1.29	3.0	1.41	2.4	O .26	.47	61.0	70.2	233
237	45	100	-.29	.23	1.30	3.1	1.40	2.3	P .25	.47	57.0	70.3	240
234	47	100	-.18	.23	1.04	.5	1.40	2.3	Q .42	.47	67.0	70.2	237
235	85	100	2.20	.31	1.07	.4	1.39	1.0	R .32	.40	86.0	86.4	238
115	55	100	.23	.23	1.13	1.4	1.34	2.1	S .36	.48	69.0	70.9	118
133	48	100	-.13	.23	1.21	2.2	1.33	2.0	T .31	.47	61.0	70.2	136
250	63	100	.66	.24	1.13	1.2	1.32	1.7	U .37	.48	69.0	73.5	253
305	42	100	-.45	.23	1.19	2.0	1.31	1.7	V .32	.46	65.0	70.6	308
178	71	100	1.14	.25	1.11	.9	1.29	1.3	W .37	.46	76.0	77.4	181
185	40	100	-.55	.23	1.28	2.8	1.24	1.3	X .27	.46	61.0	70.9	188
120	59	100	.44	.23	1.08	.8	1.27	1.6	Y .41	.48	70.0	72.0	123
207	68	100	.95	.24	1.08	.7	1.27	1.3	Z .40	.47	73.0	75.8	210
276	57	100	.34	.23	1.19	1.8	1.27	1.6	.34	.48	67.0	71.4	279
312	51	100	.02	.23	1.02	.2	1.27	1.7	.43	.47	71.0	70.2	315
254	54	100	.18	.23	1.20	2.1	1.25	1.6	.33	.48	63.0	70.6	257
302	77	100	1.54	.27	1.03	.3	1.25	.9	.40	.45	82.0	80.7	305
219	79	100	1.69	.28	1.06	.4	1.25	.9	.37	.44	82.0	81.9	222
15	73	100	1.26	.26	1.14	1.1	1.24	1.0	.35	.46	73.0	78.5	16
314	64	100	.72	.24	1.23	2.0	1.24	1.3	.32	.48	65.0	73.9	317
214	53	100	.13	.23	1.13	1.4	1.24	1.5	.37	.48	69.0	70.4	217
231	55	100	.23	.23	1.17	1.7	1.24	1.5	.35	.48	63.0	70.9	234
137	51	100	.02	.23	1.19	2.0	1.23	1.5	.34	.47	63.0	70.2	140
225	50	100	-.03	.23	1.15	1.7	1.23	1.5	.35	.47	68.0	70.2	228
282	55	100	.23	.23	1.08	.9	1.22	1.4	.41	.48	65.0	70.9	285
78	67	100	.89	.24	1.10	.9	1.22	1.1	.39	.47	70.0	75.3	80
236	55	100	.23	.23	1.15	1.5	1.22	1.4	.37	.48	63.0	70.9	239
79	72	100	1.20	.25	1.14	1.1	1.21	.9	.36	.46	75.0	77.9	81
169	65	100	.78	.24	1.21	1.8	1.16	.9	.34	.47	68.0	74.3	172
92	67	100	.89	.24	1.18	1.6	1.21	1.1	.34	.47	70.0	75.3	94
321	50	100	-.03	.23	1.13	1.4	1.21	1.3	.37	.47	70.0	70.2	325
BETTER FITTING OMITTED													
140	71	100	1.14	.25	.95	-.4	.78	-1.0	.52	.46	76.0	77.4	143
142	75	100	1.40	.26	.94	-.4	.76	-.9	.51	.45	80.0	79.6	145
71	84	100	2.11	.30	.92	-.4	.78	-.5	.47	.41	86.0	85.6	73

108	74	100	1.33	.26	.91	-.6	.77	-.9	.53	.46	84.0	79.0	111	
98	69	100	1.01	.25	.90	-.8	.74	-1.3	.56	.47	75.0	76.3	100	
183	69	100	1.01	.25	.90	-.8	.77	-1.2	.55	.47	79.0	76.3	186	
141	72	100	1.20	.25	.89	-.8	.78	-.9	.54	.46	81.0	77.9	144	
14	64	100	.72	.24	.89	-1.0	.80	-1.2	.56	.48	79.0	73.9	15	
151	75	100	1.40	.26	.89	-.8	.79	-.8	.53	.45	84.0	79.6	154	
255	69	100	1.01	.25	.89	-.9	.75	-1.2	.56	.47	79.0	76.3	258	
273	68	100	.95	.24	.88	-1.0	.73	-1.4	.57	.47	79.0	75.8	276	
244	78	100	1.61	.27	.88	-.8	.76	-.8	.53	.44	85.0	81.3	247	
85	70	100	1.07	.25	.87	-1.0	.72	-1.4	.57	.47	80.0	76.8	87	
206	64	100	.72	.24	.87	-1.2	.74	-1.5	.58	.48	73.0	73.9	209	
136	66	100	.83	.24	.87	-1.2	.77	-1.3	.57	.47	78.0	74.8	139	
21	61	100	.55	.23	.87	-1.3	.76	-1.5	.58	.48	74.0	72.7	23	
110	65	100	.78	.24	.87	-1.2	.76	-1.4	.58	.47	76.0	74.3	113	
152	76	100	1.47	.27	.87	-.9	.70	-1.2	.56	.45	81.0	80.1	155	
103	74	100	1.33	.26	.87	-1.0	.78	-.9	.55	.46	82.0	79.0	106	
232	73	100	1.26	.26	.87	-1.0	.72	-1.2	.56	.46	81.0	78.5	235	
3	64	100	.72	.24	.87	-1.3	.75	-1.5	.58	.48	79.0	73.9	3	
197	59	100	.44	.23	.87	-1.4	.74	-1.7	.59	.48	72.0	72.0	200	
131	77	100	1.54	.27	.86	-.9	.70	-1.1	.55	.45	82.0	80.7	134	
116	64	100	.72	.24	.86	-1.3	.75	-1.5	.58	.48	77.0	73.9	119	
64	59	100	.44	.23	.86	-1.5	.78	-1.4	.58	.48	76.0	72.0	66	
114	65	100	.78	.24	.86	-1.3	.78	-1.2	.58	.47	78.0	74.3	117	
73	72	100	1.20	.25	.85	-1.2	.76	-1.0	.57	.46	83.0	77.9	75	
227	73	100	1.26	.26	.85	-1.1	.77	-1.0	.57	.46	81.0	78.5	230	
106	66	100	.83	.24	.84	-1.4	.71	-1.7	.60	.47	80.0	74.8	109	
1	70	100	1.07	.25	.84	-1.3	.70	-1.5	z .59	.47	78.0	76.8	1	
233	59	100	.44	.23	.82	-1.9	.82	-1.1	y .60	.48	82.0	72.0	236	
8	53	100	.13	.23	.82	-2.0	.79	-1.4	x .60	.48	81.0	70.4	8	
301	65	100	.78	.24	.82	-1.7	.72	-1.6	w .60	.47	80.0	74.3	304	
30	66	100	.83	.24	.82	-1.6	.70	-1.7	v .61	.47	80.0	74.8	32	
184	72	100	1.20	.25	.82	-1.5	.82	-.7	u .58	.46	83.0	77.9	187	
264	59	100	.44	.23	.82	-1.9	.72	-1.8	t .61	.48	78.0	72.0	267	
148	69	100	1.01	.25	.82	-1.5	.71	-1.5	s .60	.47	81.0	76.3	151	
105	70	100	1.07	.25	.82	-1.5	.81	-.9	r .58	.47	82.0	76.8	108	
28	66	100	.83	.24	.81	-1.7	.73	-1.5	q .61	.47	76.0	74.8	30	
31	65	100	.78	.24	.81	-1.8	.72	-1.6	p .61	.47	80.0	74.3	33	
94	71	100	1.14	.25	.81	-1.5	.69	-1.5	o .60	.46	80.0	77.4	96	
97	66	100	.83	.24	.81	-1.8	.69	-1.8	n .61	.47	80.0	74.8	99	
54	64	100	.72	.24	.80	-1.9	.72	-1.7	m .62	.48	81.0	73.9	56	
198	81	100	1.85	.29	.80	-1.2	.60	-1.3	l .57	.43	86.0	83.3	201	
275	66	100	.83	.24	.80	-1.8	.71	-1.6	k .62	.47	76.0	74.8	278	
190	64	100	.72	.24	.80	-2.0	.73	-1.6	j .62	.48	83.0	73.9	193	
126	54	100	.18	.23	.79	-2.4	.68	-2.3	i .63	.48	77.0	70.6	129	
215	59	100	.44	.23	.78	-2.3	.72	-1.8	h .63	.48	82.0	72.0	218	
45	65	100	.78	.24	.76	-2.3	.67	-1.9	g .64	.47	82.0	74.3	47	
51	71	100	1.14	.25	.76	-2.1	.60	-2.0	f .64	.46	84.0	77.4	53	
43	73	100	1.26	.26	.75	-2.0	.74	-1.1	e .62	.46	87.0	78.5	45	
143	67	100	.89	.24	.74	-2.4	.64	-2.1	d .65	.47	80.0	75.3	146	
37	79	100	1.69	.28	.73	-1.8	.49	-2.0	c .64	.44	84.0	81.9	39	
248	69	100	1.01	.25	.70	-2.8	.60	-2.2	b .68	.47	85.0	76.3	251	
154	75	100	1.40	.26	.69	-2.4	.50	-2.3	a .68	.45	84.0	79.6	157	
MEAN	62.8	100.0	.67	.24	1.00	.0	.99	.0			74.1	74.3		
S.D.	9.1	.0	.52	.01	.12	1.1	.22	1.1			5.9	3.2		