

SEMI STANDARDIZATION OF A TEST OF SECONDARY SCHOOL MATHEMATICS

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Abstract

Present study intended to semi standardize a test of secondary school Mathematics for the students of 9th class. Two Mathematics Achievement Tests (MATs) were prepared from 302 items of previous papers of BISEs of Punjab province, each having 50 MCQs. A sample of 280 students from tehsil Quaid Abad of Khushab District consisted of 142 females and 138 males' respondents was drawn from the population. MATs were administered on the respondents. Reliability of the tests and traditional item analysis was computed through MS Excel. For reliability of parallel form MATs correlation coefficient was computed. The value of correlation coefficient was 0.64. Through item analysis, item discrimination index and item difficulty index of each item of the test was computed. There was a lot of repetition in the items of Boards of Intermediate and Secondary Education. Violation of standard rules was there for item construction. Coverage of curriculum was incomplete. As a result of item analysis total 34 items were rejected, 6 items were rejected on the basis of both Discrimination index and Difficulty index, 27 items were rejected due to discrimination index, 13 items were rejected on the basis of difficulty index, 2 items were difficult and 11 items were easy. For Rasch calibration PROX method was used for item difficulty and person ability. On the basis of Rasch calibration 2 items were rejected. Rasch latent continuum, Item

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characteristic curve and person characteristic curve were drawn according to Rasch model which made the data clearer and more understandable.

Keywords: Semi standardized test, Mathematics Achievement Tests, Item Analysis, Rasch Model, BISE

Introduction

The subject of mathematics deals with quantities, calculations and measurements. Its value for human societies is very essential since it is concerned with each field of life. Nobody can be able to perform anything without including mathematics in its practice; either it is job related, business or related to households. Therefore, we can say, mathematics is very important, and we should give emphasis to the knowledge of mathematics.

Evaluation and assessment are also key component of learning process; as the process of assessment helps to test out the knowledge of the students. Assessment is a fundamental element of the instructive procedure. It gives the complete information concerning the learning of the learners. Linn & Gronlund (2008) defined assessment as “any of a variety of procedures used to obtain information about the student performance”. There are special tools of assessment by the help of which the performance of the students can be measured. The tools of the assessment are observations, class projects, oral questioning and paper-and-pencil tests etc. Mostly paper-and-pencil tests are used to evaluate the performance of the students.

A test is an instrument in which a set of questions is presented to the students to measure their performance. There is no single definition of the term “test”; different authors define tests in different ways. Chaudhary & Malik (n.d) define the test as “The set of items or questions presented to one or more individuals under specified conditions for purpose of measurement”. Another definition of test by Linn & Gronlund (2008) is “A test is a particular type of assessment that typically consists of a set of questions administered during a fixed period of time under personally comparable conditions for all students”.

There are different types of tests which are used to assess the knowledge and skills, and behaviour (Chaudhary & Malik, n.d). The tests used in educational settings are achievement tests. There are two types of the achievement tests that are being frequently used in the educational institutions to evaluate the performance of the students (Bichi and Talib 2018). These are informal achievement tests and standardized achievement tests. Chaudhary & Malik (n.d) defined standardized tests as “tests that are uniformly developed, administered and scored”. The standardized achievement tests are carefully constructed and are norm-based achievement tests of the representative group. These tests are administered on

representative group of the students under the same conditions and used to measure the learning of school subject the students have already learned (Bagin, 1989).

Standardized achievement tests are very useful tool of the assessment and are used to measure the learning of the students. So, by keeping in mind the importance of the subject of mathematics for the students, the researcher intended to semi standardize a test of mathematics for the students of 9th class.

Subsequently “*Semi Standardization*” refers to the process of construction, administration and analysis of each test item of MATs is semi standardization, “*Reliability*” means the value of correlation coefficient of the instrument, “*Item analysis*” indicates the process of judgment of each item of the test, “*Item difficulty*” shows the percentage of correct responses of the students, “*Item discrimination*” depicts the ability of an item to discriminate between high and low achievers in this study.

The objectives of the study were to:

1. construct the semi standardized test of secondary school mathematics.
2. find out the person ability and item difficulty with the help of Rasch Model.

Methodology

This section deals with the method and procedure adopted for present study. The study was conducted for the semi-standardization of a test of Secondary School Mathematics. The researcher named this test as Mathematics Achievement Tests (MAT). This MAT included only Multiple-Choice Questions (MCQs).

Researcher tried to access the previous examination data (results of students) from Boards of Intermediate and Secondary Education (BISEs) to prepare a Mathematics Data Bank (MDB) for the purpose of data analysis. The authorities of BISEs were reluctant to provide the related data for their data confidentiality.

All the students of 9th class studying in the secondary schools (SS) and the higher secondary schools (HSS) of *tehsil* Quaid Abad of Khushab district (province of Punjab) constituted the population for this study.

Convenient sampling technique was used for the sample selection. sample was selected from the four schools of *tehsil* Quaid Abad of Khushab district. The students who participated in both MAT_A and MAT_B were 280. Out of 280 respondents 142 students were female and 138 students were male students. Female students of the sample were selected from three girl’s schools and male students were selected from only one boy’s school. Sample from three girl’s schools were selected for the equal proportion of girls’ and boys’ students in the sample.

Two equivalent form MATs for the students of 9th class were prepared as instrument for the purpose of data collection of the present study. Each MAT contained fifty (50) MCQs.

MATs were developed from previous papers of the BISEs. Only MCQs of the papers were used to prepare MATs. Only those previous papers were included for the study, which were used in split scheme of examination (separate BISEs examination for class 9 and class 10).

Phase I: Previous papers of all the boards were collected through different resources like electronic sources and by the resource persons through mail.

Phase II: Papers of each board which were received from different sources were typed and placed in a single file with the name of that board. That file had all the previous papers of that board with name of board and year of administration.

Phase III: All papers of each board were combined at a single place without year of administration and repeated items were deleted. At this phase eight files were prepared with the combined papers of each board without repetition of any item.

Phase IV: In this phase all eight files of the papers were combined in a single file but with the identity of each board.

Phase V: After combining all the papers in a single file in the next phase identity of the boards were finished. At this stage total 630 items were obtained from all previous papers of the BISE of province Punjab.

Phase VI: Out of total 630 items repeated items were deleted. After deleting the repeated items total remaining items were 302 from all the boards.

Phase VII: At this stage of instrument development these 302 items were arranged according to the content of textbook of Mathematics of Punjab Textbook Board Lahore.

Table 1 (Appendix-A) showed the arrangement of 302 items according to the contents of textbook of Mathematics of Punjab Textbook Board Lahore. The table described the distribution of items with respect to topics and subtopics of the textbook of Mathematics of Punjab Textbook Board Lahore. Table 1 gave a clear picture of distribution of items with respect the chapter wise distribution of items.

A brief summary of content coverage with respect to chapter wise distribution is given in table 2 (Appendix-B). The table also describes which item was selected for the MATs.

Phase VIII: Finally, hundred (100) MCQs were selected from these 302 items. These 100 items were selected in a way that any topic or subtopic of the textbook of Mathematics covered in MCQs of the previous papers of BISEs was not ignored. These items were translated in Urdu also as these items were prepared in English medium. After that Mathematics Achievement Test form, A (MAT_A,) and Mathematics Achievement Test Form B (MAT_B,) were prepared. Each MAT contained fifty (50) MCQs. These MATs were prepared in such a way, that the items with odd serial numbers were put in MAT_A and the items with even serial numbers were put in MAT_B. Table 3(Appendix-C) showed the distribution of papers with respect to Board and Year.

The instrument used for the study was prepared from the previous papers of the BISEs. Most of the selected items were being used in BISEs exams more than one time. So, keeping this point in mind pilot testing was not done.

The tests were administered with the help of school heads and school teachers to the sample of the students by using convenient sampling technique. By the help of these tests (MAT) data were collected for the present study.

For the reliability coefficient correlation was computed. Data were analysed by computing the item difficulty index, item discrimination index and distracters effect of each item. Traditional item analysis and reliability coefficient were computed by MS Excel 2007.

For maintaining the reliability of the instrument, the MAT was split in two halves. Two equivalent MATs were administered in the study, so correlation of the MATs was computed to find out the reliability of the MATs. It was 0.64. That is a positive acceptable correlation for the reliability of the instruments.

Item analysis of a test helps to find out the quality of individual test items as well as it also helps to assess the quality of a test as a whole. For item analysis two methods were used, first one is traditional item analysis second Rasch model.

The researcher used following procedure for traditional item analysis.

Difficulty Index (P)

The difficulty index of each test item was computed by the help of the following formula.

$$P = 100 R/T$$

P = Item difficulty index

R = Number of the students who got the item right

T = Total number of students who tried the item (Linn and Gronlund 2008).

Items with values ranging from 20% to 80% were selected while rest of the items was discarded. The following criterion was followed in the study of Shah (2005) and Naseem (2011).

Discrimination INDEX (D)

The discrimination index of each test item is calculated by the help of the following formula.

$$D = (RU - RL)/(0.5T)$$

D = Discrimination index

RU = students in the upper group who get the item right

RL = students in the lower group who get the item right

T = Total number of the students (Linn and Gronlund, 2000)

In the formula 27% students of upper and 27% of lower group were selected for the purpose of test analysis. As mostly researchers use total 54% of the students for this purpose. For example (Higrorjo and Jaleel, 2012; Backhoff, Larrazolo and Rosas, 2000; Mitra et al, 2009; and Sim and Rasiah, 2006) used 27% upper and 27% lower group of the students for item analysis.

Items with values ranging from 0.20 to 0.80 were selected while rest of the items was discarded. The following criterion was followed in the study of Shah, (2005) and Naseem (2011).

Effectiveness of distracters was computed with the help of discrimination index.

Results

This section deals with analysis and interpretation of the data. The purpose of the study was to semi standardize of a test of secondary school mathematics. The data were analysed through traditional item analysis and Rasch method. Results of the study were arranged in the following sequence.

1. Items under study
2. Traditional item analysis
3. Application and analysis of items through Rasch model

Items were studied and the following important points were markedly observed.

- The researcher observed a lot of repetition of items in the same board. For example, from BISE Lahore the researcher succeeded to gather 140 items but as the table 4 shows after deleting the repeated items, there were only 90 items of BISE Lahore.
- Even that the repetition was observed by the researcher in the papers of group I and group II of the same year and same day.

- There was a lot of repetition of items among all the BISEs. Means one BISE is repeating the item of any other board in the same year or in any other year.
- The changed item appeared faulty.
- If in some BISE anyone had tried to make some changes in the repeated item, all the alternatives of that item were wrong. The changed item was fault.
- Practice of using faulty items again and again
- Faulty items were also observed in the BISEs papers other than the items that were tried to be change due to repetition of the items.

Violation of Standard practice

Most of the MCQs were taken from those items which are given at the end of the exercises or at the end of textbook.

Incomplete Coverage of Curriculum

Some topics and subtopics are frequently assessed from all the BISEs, while there are such topics also which are not assessed by any of the Board. For example, there are 18 theorems in textbook of mathematics of 9th class. Only seven theorems are assessed while eleven theorems are not assessed by any Board even a single time.

Traditional Item Analysis

Two parallel form achievement tests MAT_A and MAT_B of the subject of Mathematics of fifty items each was administered on a sample of 280 male and female students of *tehsil* Quaid Abad district Khushab, for the purpose of semi-standardization of test items. The type of the items selected for tests was MCQs. As the MATs were equivalent form, so both the MATs were combined for the purpose of semi-standardization of the test items and were considered as a single test. Traditional item analysis of all the hundred items was made with MS Excel. Discrimination index and item difficulty index were calculated for each item of the MAT.

Explanation of Table 4 (Appendix D)

Column 1: Gave the allocated number of each item. There are 100 items in the MAT, so item no. goes from 1 to 100.

Column 2: It represented the distracters of the tested items. Each item had four distracters. For example, item no. 83 had four distracters, A* is the correct answer.

Column 3: It gave the choice frequency and percentage (%) of the students who attempted the distracter.

Column 4: Notified the discrimination index of each of the distracter. The formula used to find out the discrimination index was discussed.

Column 5: Told the status of the item on the basis of item discrimination index. The range item acceptance and item rejection are given.

Column 6: Notified the difficulty index of each of the distracter. The formula used to find out the discrimination index was discussed.

Column 7: Informed about the difficulty status of the tested items based on difficulty index; the criterion is given.

Based on choice frequency, the decision of item rejection or acceptance was not made. It was calculated only to represent a clear and simple picture of choices made by the students. For example, from the table 4.1 it can be shown easily that the correct answer of item no. 33 was attempted by 92 % respondents. Each of other distracters was attempted by less than 5 % students.

Table 1 reflected that the item no. 57 was correctly attempted by 80% students. The distracter “A” of item no. 57 was selected by only one (1) out 280 students that is 0.35 % of all the students.

Discrimination Index

Discrimination index were calculated for each item of the test. For this purpose, 27% low achievers and 27% high achievers were selected. The items having discrimination index less than 0.20 and more than 0.80 were rejected as they were not discriminating between low achievers and high achievers. On the basis of Discrimination index out of total 100 items 71 items were selected as these items were discriminating very well between low and high achievers. Item no. 38 was a faulty item, as all the alternatives of this item were wrong, so this item was discarded from the data set.

Table 5 (Appendix E) Summary of Item Discrimination Index

In Table 2 sr. no. 1 reflected the items that had been rejected on the basis of discrimination index. These items had discrimination index less than 0.20 which was similar to the study of Boopathiraj & Chellamani (2013). These results showed that these items failed to discriminate between low and high achievers. The items could not attract a reasonable ratio of high achievers that could discriminate high achievers from the low achievers.

Out of above 27 items shown in table 6, item no. 6, 48,49,84,92 and 97 had a negative discrimination. The negative item discrimination indicated these items attracted low achievers more than high achievers as indicated by Hingorjo & Jaleel, (2012). The discrimination index of item no. 62 was 0.00 which depicted that the item attracted equal no. of high achievers and low achievers.

Sr. no. 2 revealed that no item had the discrimination index greater than 0.80.

Table 2 sr. no. 3 expressed those 72 tested items fall in the acceptable range. From the table it can be concluded that majority of the tested items enjoyed the acceptable range Of discrimination index.

Difficulty Index

In the process of item analysis item difficulty of each item of the test was computed. The items had difficulty index less than 20% were nominated as difficult items. Only two items were difficult. The items had difficulty index greater than 80% were nominated as easy items.

Eleven (11) items were easy according to the analysis. Rests of 86 items were moderate as the range of difficulty index of these items was lying within “20% to 80%”. This acceptance range was also used by Shah, 2005 and (Naseem, 2011).

Table 6 (Appendix F)

Summary of Difficulty Index

Table 3 reflected those 13 items which were rejected on the basis of difficulty index. In the above table sr. no. 1 described the items had difficulty index less than 20%. These items are nominated as difficult items. As these items did not fall in the acceptable range of difficulty index so were rejected. The same result was reported in the study of Shah, 2005 and Naseem, 2011. In table 4.3 sr. no. 2 represented the items had difficulty index more than 80%. So, these items were also rejected as these items did not fall in the acceptable range of item acceptance.

A same criterion of item rejection was also followed by Boopathiraj & Chellamani (2013). Remaining 86 items were not rejected as these items’ lye in moderate range of difficulty index. The researcher concluded from these results that most of the items have acceptable range of item acceptance.

Items Rejected on the Basis of D and P

Some of the items were rejected on the basis of both the discrimination.

Table 7 (Appendix G)

Items Rejected on the Basis of D and P

Table 4 indicated the whole summary of rejected items on the basis of item analysis. In the table 4.4 column 3 reflected those six (6) items which fall in both rejection regions the item difficulty and items discrimination. The items are 7, 33, 48, 57, 88 and 92. In this way total 33 items were rejected out of 99 items on the basis of traditional item analysis.

Correction of Items

Some of the items were suggested for the correction. Those items are given in table 4.5.

Table 8 (Appendix H) Correction of Items

Item no. 34, 52, 53, 66, 68, 79, 81, 95 and 100 are the items which need improvement. As in these items difficulty index of the correct alternative is less than any one of the distracters of item. For example, in Item no. 68 correct alternative is "A*" and its facility index is 38.19 but the facility index of alternative "D" is 44.44 which shows that most of the students are attempting alternative "D" instead of the correct alternative. So, the value of the alternative "D" should be replaced by some other value. In this way all these nine items need improvement.

The values of the alternatives that had more difficulty index than the correct alternatives should be replaced by some other values.

Rasch Model

Two parallel form achievement tests MAT_A and MAT_B of the subject of Mathematics of fifty items each was administered on a sample of 280 male and female students of *tehsil* Quaid Abad district Khushab, for the purpose of semi-standardization of test items. The type of the items selected for tests was MCQs.

Traditional item analysis depends on students who are taking the test. In the same way item difficulty and item discrimination depends on the sample. If sample is changed, the standardized measurement is no more valid. So, there is no true "standardized" measurement in traditional item analysis as it is based on the sample. The Rasch approach of item analysis does not depend on the sample and the items. The item calibration is sample free and the person measurement is item free, this quality of the Rasch model gives it a specific objectivity.

Prox Item Calibration

With the help of item scores item calibration was computed. The method that was used for the item calibration was Prox method.

Prox method works fairly well for typical distributions of items and persons. For a test of "L" items given to a sample of N' persons; delete all items no one gets right and no one gets wrong and all persons with none right and none wrong until no such items or persons remain (Wright, 1978).

Data obtained from the MATs did not contain such an item that was answered correctly by everyone or no one. In the same way there was no person who had answered all the items correctly or no item correctly. Due to this reason no item or person was removed from the data. Prox item calibration and Prox person measurements are given in the table 4.6 and 7; these

calculations were made possible by the help of MS Excel 2007.

Application and Analysis of Items through Rasch Model

Table 9 (Appendix I)

Explanation of the Table 9 Prox Item calibration (Column 1 to 8)

Column 1: Gives the name of each item (i) since there are 100 items (L), the item score index (i) goes from 1 to 100.

Column 2: Gives the item score which characterized each item (si) i.e., the number of persons who got a particular item correct. (Item 36 was correctly done by 133 persons.

Column 3: Converts the item scores into proportions correct among the sample of N=280

$$P_i = S_i / N \text{ (for item 36) } p_i = 133/280 = .48$$

Where p_i = Correct proportion of item.

S_i = Number of correct responses.

N = Total number of students.

Column 4: is the conversion of proportion correct (p_i) into the proportion incorrect ($1-p_i$)

For Item 36, proportion incorrect = $1 - .48 = .53$

Column 5: is the conversion of this proportion into logits incorrect. Each item score logits is the natural log of its proportion incorrect divided by its proportion correct.

$$X_i = \ln \frac{(1 - P_i)}{P_i}$$

For item 36, $X_i = 0.10$

At the bottom of column 5, the mean (M) of the logit incorrect is written;

$$M = \frac{\sum X_i}{L} = \frac{\text{Sum of Logit Incorrect}}{\text{No. of Items}}$$

$$M = -0.06$$

Column 6: gives the values of column 5 centred by subtracting their mean. These are the initial item calibrations.

$$d_i = X_i - M$$

For item 36 $d_i = 0.17$

At the bottom of column 6, the variance of initial item calibration is written.

$$U = \frac{\sum (d_i)^2}{L-1} = \frac{\text{Sum of square of all initial item calibration}}{\text{No. of items}-1}$$

$$U = 0.93$$

Column 7: In column 7 the value of “y” is written. “Y” is item difficulty expansion factor due to sample spread. It was calculated by the following formula:

$$y = \left[\frac{1 + v/2.89}{1 - uv/8.35} \right]^{1/2}$$

Y= 1.03

Column 8: It gives the correct item calibrations obtained by multiplying each initial value in *column 6* by the expansion factor of 1.03 (*column 7*). It gives the final item calibration for each item (d_i).

$$d_i = y_i \cdot d_i$$

For item 36 the final item calibration = $1.03 \times 0.17 = 0.17$

Prox Person Measurement

Total no. of items: 100 (L)

Total no. of Students: 280 (N)

$V = 0.29$

Table 10 (Appendix J)

Explanation of the Table 10 (Column 1 to 9)

Column 1: gives the frequency of persons observed at each score. The total number of persons is equal to the sample, $N = 280$ that is equal to the sum of these frequencies.

Column 2: Shows the Blocks assigned to each person. Blocks were made against each possible score. The Blocks ranged from B1 to B99. In Blocks B1 to B17, B86 to B88 and in the same way in Blocks B90 to B99 there was no person.

Column 3: Gives each possible score from 1 to 99 (r) (As no score (0) and perfect score (100) so scores are excluded from the calibration).

So, $r = 1$ to $L-1$

r goes from 1 to 99

Column 4: Is the proportion of each score on a test of 100 items (pr)

$$Pr = r/L$$

Where Pr = Proportion correct score

r = Possible score

L = Total No. of items.

(In case of any persons from block B76)

$$Pr = \frac{76}{100} = 0.76$$

Column 5: is the conversion of proportion correct (pr) into the proportion incorrect ($1-pr$)

For persons in Block 76, $1-pr = 1-0.76 = 0.24$

Column 6: is the logit correct for that proportion using calculator.

$$vr = \ln \frac{pr}{1-pr}$$

For persons in Block 76, $vr = 1.15$

Column 7: Repeats the values of column 6. These are the initial person measures (Br) prior to correction for test width.

The variance (V) for the distribution of scores is given at the bottom of column

$$V = \frac{\sum[(br)^2 \times f]}{N - 1}$$

$$V = 0.29$$

Column 8: gives the values of person ability expansion factor (X). The person ability expansion factor(X) due to the test width is:

$$X = \left[\frac{1 + u/2.89}{1 - uv/8.35} \right]^{1/2}$$

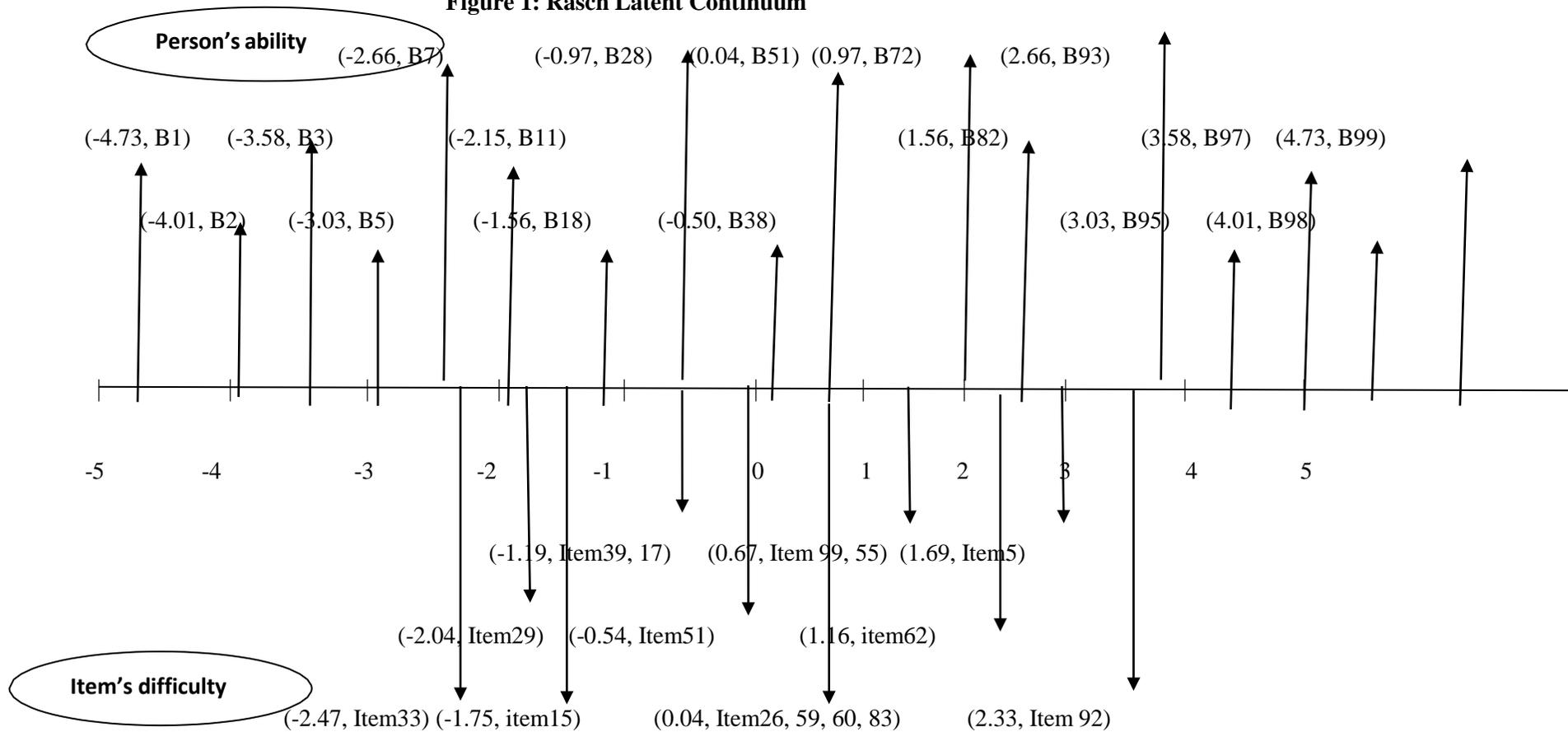
$$X = 1.03$$

Column 9: gives the corrected person measurements obtained by multiplying each initial value in column 7 by expansion factor (X). It gives the final person measurement.

$$br = X.br$$

For any person in Block76, 1.19 is the value of final ability measurement.

Figure 1: Rasch Latent Continuum



Identification of the Position of Items and Persons

The person parameter and the item parameter are both believed to be computing the same thing; and this means that all the items in the test must be concerned with the similar trait or variable. Rasch calibration sets out to situate the measurements of person achievement and item difficulty on the same scale (Figure1) and uses the same units for both. The process uses the variable to trace the position of the difficulty measurement of each item and positions of the person achievement measures which corresponds the possible raw score on the test.

The procedure checks the patterns of the students' performance on each item and on the test as a whole, take out a variable of student achievement from the data, estimates the item difficulty measures and person achievement measures on the scale and permits for the identification of those students whose performance are qualitatively different from the performance of the greater part of students. Fig. 1 tells latent continuum showing position of items and persons on a vertical line.

As there were 99 blocks of item difficulty measures (column 8 table 10) and final person ability estimates (column 9 table 11). To identify the position of items and persons in all 99 blocks, it could not be shown in a better way on a single line. So 10 items of different difficulty level were taken and in the same way 17 blocks relating to different ability groups were taken for analysis.

Final item difficulty measures (column 8 table 10) are shown by arrows in the lower half and final person ability estimates (column 9 table 11) are given in the upper half of the figure. The persons on the continuum are arranged with increasing ability level from left to right, and in the same way items were also arranged from left to right on the same continuum with increasing difficulty level. Points on vertical line give a clear picture of each item and each person. Any person can be compared with any other person and any item can be compared with any other item. Moreover, the encounter of a person with any item could also be observed.

Fig 4.1 explained that item 92 the hardest item. Item 33 according to the figure 1 was very easy. Similar results were found in the studies of (Hashmi, 2000; Shah 2005 and Qadir, Gilani, & Hameed, 2012).

From figure 1, it could be assumed that persons in Block18 had a good probability of getting item 33, 29 and 15 correct and had relatively less chances in case of items 51, 39, 17, 26, 59, 60 and 83, but they had a large difficulty in obtaining a right answer for items 99, 55, 62, 5, 48 and 92 as these are faraway their reach (ability). The example gave an idea that the person of a block on the same continuum would attempt the items correctly occurring on the left of it, and all the items occurring on the right of it would not attempt correctly. Related results were found in the study of Hussain, 2010; Naseem, 2011 and Qadir, Gilani, & Hameed, 2012.

Item and Person Characteristic Curve

Rasch latent continuum provides relative probability value of person and item with respect to each other. It does not provide any exact value of probability of person to answer an item. It only gives an idea about access of a person to an item for trying it correctly. In order to know definite value of probability of person to solve an item, item characteristic curve and person characteristic curve are drawn by using the following formula. Item characteristic curve and person characteristic curve were also drawn by Hashmi, 2000; Shah 2005 Hussain, 2010; Naseem, 2011 and Qadir, Gilani, & Hameed, 2012 to find out the definite value of probability of person to solve an item.

$$P = \frac{\exp(br - di)}{1 + \exp(br - di)}$$

Where

P= probability value

di= difficulty level of an item

exp= exponential function

br= ability value of a person

Table 11 (Appendix K)

Item Characteristic Curve

Series 1: Persons of block having ability value -4.73 showed 6 percent probability to solve an item with difficulty level -2.04, for the person of the same block the probability to solve an item with 0.67 difficulty level was zero percent, and the probability to solve an item with 2.33 difficulty level was also zero percent for the person of the same block.

Series 2: Persons of block having ability value 0.55 showed 93 percent probability to solve an item with difficulty level -2.04, for the person of the same block the probability to solve an item with 0.67 difficulty level was 47 percent, and the probability to solve an item with 2.33 difficulty level was 14 percent for the person of the same block.

Series 3: Persons of block having ability value 4.73 showed 100 percent probability to solve an item with difficulty level -2.04, for the person of the same block the probability to solve an item with 0.67 difficulty level was 98 percent, and the probability to solve an item with 2.33 difficulty level was 92 percent for the person of the same block.

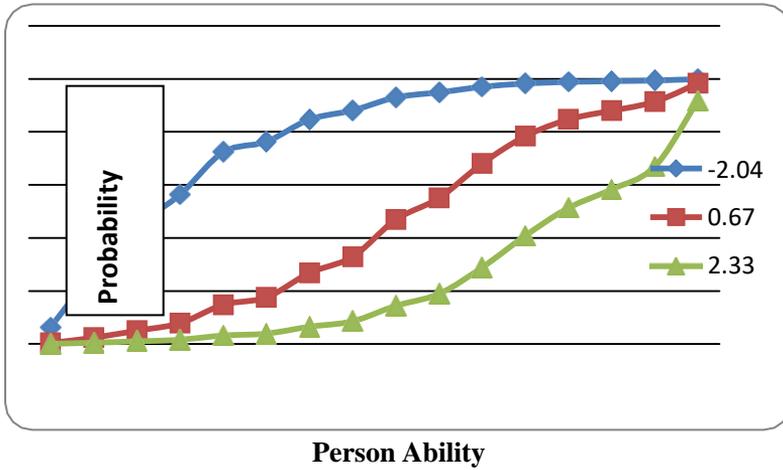


Figure 2: Item Characteristic Curve

Table 12 (Appendix L)

Person Characteristic Curve

Series 1: Persons of block having ability value -2.15 showed 58 percent probability to solve an item with difficulty level -2.47, for the person of the same block the probability to solve an item with 0.80 difficulty level was 5 percent, and the probability to solve an item with 2.33 difficulty level was also one percent for the person of the same block.

Series 2: Persons of block having ability value 0.17 showed 93 percent probability to solve an item with difficulty level -2.47, for the person of the same block the probability to solve an item with 0.80 difficulty level was 35 percent, and the probability to solve an item with 2.33 difficulty level was 10 percent for the person of the same block.

Series 3: Persons of block having ability value 1.96 showed 99 percent probability to solve an item with difficulty level -2.47, for the person of the same block the probability to solve an item with 0.80 difficulty level was 76 percent, and the probability to solve an item with 2.33 difficulty level was 41 percent for the person of the same block.

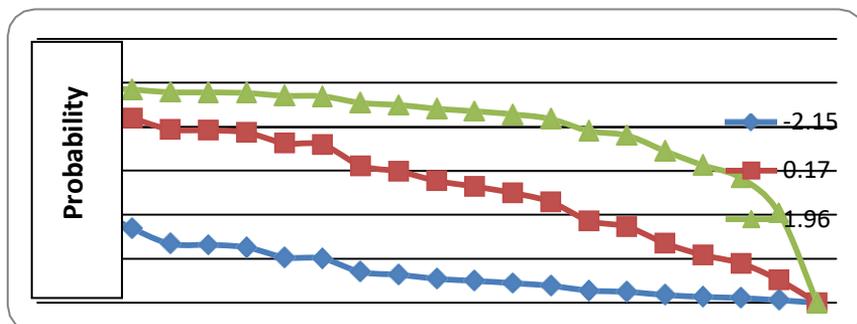


Figure 3: Person Characteristic Curve

Item Difficulty

Following criteria was used for item selection and item rejection

- If discrimination index was less than 0.2 or greater than 0.8 the item was rejected otherwise selected. Same criteria were used by Shah, 2005 and Naseem 2011.
- If the item had difficulty index greater than 80% it was rejected because it was an easy item.
- If difficulty index was less than 20% then the item was also rejected because it was a difficult item.
- If difficulty index was 20% to 80% the item was selected. Boopathiraj & Chellamani (2013) also used the same range for item rejection.

In the second phase item analysis was done by Rasch model. With Rasch calibration person ability and item difficulty was computed.

Discussion & Conclusion

Reliability of the MATs was adequate, so MATs were reliable. Twenty-seven (27) items were discarded on the basis of discrimination index (Shah, 2005). Among these 27 items only 1 item had zero (0) discrimination index. Six (6) items had negative discrimination index.

No item was rejected on the basis of high discrimination index as all discarded items had discrimination index less than 0.2 (Fatima, z. Shahzadi, U and Ali, G. 2020). Total Thirteen (13) items were rejected on the basis of difficulty index as the range of these items did not fall in between 20% to 80% that was also described by Shah (2005) and Boopathiraj & Chellamani (2013). Two items were discarded due to greater difficulty index (Naseem, 2011; Fatima, Z. Tirmizi, S. et al., 2015).

Eleven items were rejected as these items were easy. Same criteria were followed by Boopathiraj & Chellamani (2013).

On the basis of total item analysis 34 items were rejected. Six (6) items were rejected due to both discrimination index and difficulty index. Nine (9)

items were recommended for improvement, as in these items the difficulty index of the correct alternative was less than any one of the distracters of item.

Rasch latent continuum helped researcher in making item person comparison more understandable and meaningful. The studies of Hussain, 2010; Naseem, 2011 and Qadir, Gilani, & Hameed, 2012 indicated the same results.

Item characteristic curve and person characteristic curve made Rasch model clearer and more consequential that was also described by Qadir, Gilani, & Hameed (2012).

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APPENDIX A**Table 1: Distribution of Content of Mathematics**

No.	Topic	Subtopics	Sub subtopic	Item No.	Total
1.1	Introduction	sets and its elements, presentation of a set, definitions, (null set/ empty set, finite set, infinite set, subset, (proper and improper subset), power set, equal sets		1-12	15 12
	1.1.1 operations on sets	1. union of sets		13	1
		2. intersection of two sets		14	1
		3. difference of two sets		15	1
	1.1.2 universal set			0	0
	1.1.3 compliment of a set			0	0
	1.1.4 equivalent sets			0	0
	1.1.5 one to one correspondence			0	0
	1.1.6 disjoint sets			0	0
	1.1.7 overlapping sets			0	0
1.2	some important sets and their notations	1.2.1 set-builder notation		16-19	4 4
1.3	Operations of union and intersection on three sets				2
	1. associative properties of union of sets			20	1
	2. associative property of intersection of sets				
	3. distributive property of union over intersection				
		1.3.1 De Morgan's Laws		21	1
1.4	Operations on sets through Venn-diagram	1. commutative property of union of sets		0	0
		2. commutative property of intersection of sets			
		3. associative property of union of sets			
		4. associative property of intersection of sets			
		5. distributive property of union over intersection of sets			
		6. distributive property of intersection over union of sets			

1.5	Difference of Sets by Venn-diagram				3
		Introductory lines 1. when set A and B are overlapping sets 2. when set A and B are disjoint 3. when $B \leq A$	22		1
		1.5.1 complement of a set by Venn-diagram	0		0
		1.5.2 complement of union and intersection of two sets	23		1
		1.5.3 De Morgan's Laws through Venn-diagram	24		1
1.6	Ordered pairs				21
		Introductory part	25-29		5
		1.6.1 Cartesian product of sets	30-34		5
		1.6.2 Cartesian coordinate system and Cartesian plane	35-45		11
1.7	Binary Relation Domain and range of a binary relation				9
			46-48		3
			49-54		6
	1.7.1	Function	0		0
		Into function Onto function One-to-one function Bijective function			
2.1	Introduction Introductory part			55	4 1
	2.1.1 Properties of Rational numbers	1. closure property w.r.t. addition and multiplication 2. commutative property w.r.t. addition and multiplication 3. associative property w.r.t. addition and multiplication 4. additive identity 5. additive inverse 6. multiplicative identity 7. multiplicative inverse 8. distributive property of multiplication over addition	56		1

	2.1.2. irrational numbers	terminating decimal fractions recurring and non-terminating decimal fractions non-recurring and non-terminating fractions		0	0
	2.1.3 square root			57-58	2
2.2	qth root of x			59-65	7
2.3	real numbers				6
	2.3.1 Properties of real numbers			66	1
		(i) closure property w.r.t. addition (ii) Commutative property w.r.t. addition (iii) Associative property w.r.t. addition (iv) Additive identity (v) additive inverse (vi) closure property w.r.t. multiplication (vii) commutative property w.r.t. multiplication (viii) associative property w.r.t. multiplication (ix) multiplicative identity (x) multiplicative inverse (xi) Distributive property of multiplication over addition		67-68 69	2 1
2.4	Properties of real numbers	Equality	(i) reflexive property (ii) symmetric property (iii) transitive property (iv) additive property (v) multiplicative	72	4 1
			property (vi) cancellation property w.r.t. addition (vii) cancellation		

			property w.r.t. multiplication		
		Inequality	(i) Trichotomy Property (ii) Transitive property (iii) Additive property (iv) Multiplicative property (v) Inequality multiplicative inverse	73 74-75	1 2
2.5	Surds			76-90	15
2.6	exponent or index			91-92	2
2.7	Laws of Exponents	(i) Law of sum of powers (ii) Law for power of product (iii) Law of power of power (iv) Law of quotient of powers with same base (v) Law of power of fraction		93-94 95 96 97-103	11 2 1 1 7
2.8	Rational Exponents			104-111	8
3.1	Scientific notation			112-121	10
3.2	Logarithm			122-134	13
3.3	Common Logarithms				13
	Introductory part			135-136	2
		3.3.1 Characteristics and Mantissa		137-147	11
		3.3.2 Reference position			
3.4	Anti-Logarithm			148-149	2

3.5	Laws of logarithms			150-157	8
3.6	Applications of Logarithms			0	0
4.1	Introductions 1. Variables and constants 2. Co-efficient and exponent				11
		4.1.1 Algebraic expression 4.1.2 Term 4.1.3 Kinds of algebraic expressions 4.1.4 kinds of polynomial expression	(i) polynomial expression (ii) Rational expression (iii) Irrational expression (i) polynomial w.r.t. to terms (ii) polynomial w.r.t. to variables (iii) polynomial w.r.t. to degree (iv) polynomial w.r.t. to coefficients	158 159 160 161 162-167 168	1 1 1 1 6 1
4.2	Ordering of an algebraic expression	Descending order Ascending order		169	1 1
4.3	value of an algebraic expression			0	0
4.4	fundamental expressions on algebraic expressions	(i) Addition of algebraic expression (ii) Subtraction of polynomials (iii) Multiplication of polynomials (iv) Division of polynomials		0	0
4.5	Formulae	1. Formula 2. Formula 3. Formula 4. Formula		170-172 173-175 176	7 3 3 1
4.6	Elements in				5

	division of polynomials	4.6.1 remainder theorem 5. Formula 6. Formula 7. Formula 8. Formula 9. Formula 10. Formula 11. Formula 12. Formula	177 178 179-180 181	1 1 2 1
5.1	Introduction		0	0
5.2	Factorization of expression of form $a^2 - b^2$	5.2.1 factorization of the algebraic expressions of the form $ax^2 + bx + c$	182-186 187-192	11 5 6
5.3	factorization of the algebraic expressions of the form $a^3 \pm b^3$		193-197	5 5
5.4	factorization of the algebraic expressions of the form $a^3 + b^3 + c^3 - 3abc$		0	0
5.5	factorization of the expressions in cyclic order		0	0
5.6	factor theorem		0	0
5.7	Highest Common Factor (H.C.F.) of the algebraic expressions	5.7.1 H.C.F. by factorization 5.7.2 H.C.F. by division	198 199-203	6 1 5
5.8	Least Common Multiple (L.C.M.) of the algebraic expressions	5.8.1 L.C.M. by factorization Method 5.8.2 L.C.M. by division Method	204-206 207-210	7 3 4
5.9	Multiplication and Division of the algebraic factorization	5.9.1 Addition and Subtraction of the algebraic factorization	211	1 1
5.10	Square root of Algebraic expression			11
	Introductory part		212	1
		5.10.1 Square Root by factorization method	213-217 218-222	5

		5.10.2 Square Root by Division Method		5
6.1	Introduction			6
		6.1.1 Order of a matrix 6.1.2 Equal matrices	223-228	6
6.2	Kinds of matrices (i) Row matrix (ii) Column matrix (iii) Rectangular Matrix (vi) Square matrix (v) Null or zero matrix (vi) diagonal matrix (vii) Scalar matrix (viii) Unit matrix (ix) Negative of a matrix	6.2.1 Transpose of a matrix 6.2.2 Adjoint of a matrix	229 230 231 232 233-234	1 1 1 1 2
6.3	Addition of Matrices	6.3.1 Properties of Addition of Matrices Commutative property Associative property 6.3.2 Additive Identity of Matrices 6.3.3 Additive Inverse of a Matrix	235-238	4 4
6.4	Multiplication of a matrix by a real number	6.4.1 Multiplication of matrices 6.4.2 Associative property of matrices with respect to multiplication 6.4.3 Distributive properties of matrices	239-241 242	3 1
6.5	Determination of a matrix	6.5.1 Singular and non-singular matrices	243-247	5 6

	Theorem 3			277-281	5
	Theorem 4			0	0
	Theorem 5			282	1
	Theorem 6			283-287	5
	Theorem 7			0	0
	Theorem 8			0	0
	Theorem 9			0	0
	Theorem 10			0	0
	Theorem 11			288-289	2
	Theorem 12			0	0
	Theorem 13			0	0
	Theorem 14			290	1
	Theorem 15			0	0
	Theorem 16	16a.		291 292	2 1 1
	Theorem 17			0	0
	Theorem 18	18a.		0	0
	Theorem 19			0	0
9.1	Introduction				5
		9.1.1 Construction of Triangles		293-297	5
		9.1.2 When two sides and a non-included angle are given		0	0
		9.1.3 When three angles are given		0	0
9.2	Ambiguous Case			0	0
9.3	A line / A ray / line segment with reference to a triangle	Right Bisector of the sides of a triangle Bisector of the angles of a triangle Medians of a triangle Altitudes of a triangle		298 299-301 302	5 1 3 1

APPENDIX B

Table 2
Chapter Wise Distribution of Items

Chapter Name	1. Sets	2. system of real numbers	3. Logarithms	4. Algebraic expressions	5. Factorization, H.C.F, L.C.M, simplification and square root
Items	1-54	55-111	112-157	158-181	182-222
No. of items	54	57	46	24	41
Items selected for MATs	5,9,13,14, 15,17,20, 21,23,24, 28,31,43, 47,50,52	56,58,59, 64,66,67, 69,71,72, 73,75,77, 82,90,92, 94,96,100 ,101, 106,110	113,1,20, 123,127,1 35,145,14 8,156, 157	158,159,1 60,161,16 5,168,169 ,172,174, 178, 180	184,191,1 92,194,19 8,201, 205,209,2 11,212,21 5,220
Chapter Name	6. Matrices and determinants Matrices and determinants	7. Fundamental Concepts of Geometry	8. Demonstrative Geometry	9. Practical Geometry	
Items	223-249	250-272	273-292	293-302	
No. of items	27	23	20	10	
Items selected for MATs	226,231,2 33, 237,241,2 42, 244,248,2 49	251,259,2 62, 264,266,2 70	273,275,2 80,282, 285,288,2 90,291, 292	294,298,2 99, 302	

APPENDIX C**Table 3**
Distribution of Papers with Respect to Board and Year

No.	BISEs	Papers										Total	Items
		2005		2008		2009		2010		2011			
		1 st group	2 nd group										
1	Lahore	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	140	90
2	Gujranwala	✗	✗	✓	✓	✓	✓	✓	✓	✓	✓	120	98
3	Bahawalpur	✗	✗	✓	✓	✓	✓	✓	✓	✓	✓	120	93
4	Multan	✗	✗	✓	✓	✓	✓	✓	✓	✗	✗	90	68
5	D.G.Khan	✗	✗	✓	✓	✓	✓	✓	✓	✗	✗	90	73
6	Faisalabad	✗	✗	✓	✓	✓	✓	✓	✓	✗	✗	90	70
7	Rawalpindi	✗	✗	✓	✓	✓	✓	✓	✓	✗	✗	90	72
8	Sargodha	✗	✗	✓	✗	✓	✓	✓	✓	✗	✗	75	66
	Total Items	10	10	120	105	120	120	120	120	45	45	815	630

APPENDIX D

Table 4 Results of Traditional Item Analysis

Item No.	Distracters	Choice frequency (%)	Discrimination Index	Status	Difficulty Index	Difficulty Status
item 1	A	15 (5.28)	-0.07		3.47	
	B*	215 (75.70)	0.42	Select	81.94	Easy
	C	17 (5.99)	-0.11		6.94	
	D	30 (10.56)	-0.19		11.11	
item 2	A	17 (5.99)	-0.11		8.33	
	B*	246 (86.62)	0.26	Select	89.58	Easy
	C	9 (3.17)	-0.06		4.17	
item 3	D	8 (2.82)	-0.07		3.47	
	A	40 (14.08)	-0.13		15.97	
	B	69 (24.30)	-0.03		27.78	
	C*	131 (46.13)	0.40	Select	45.14	Moderate
item 4	D	25 (8.80)	-0.17		11.11	
	A	44 (15.49)	0.07		17.36	
	B	54 (19.01)	-0.11		18.06	
	C*	141 (49.65)	0.14	Reject	50.00	Moderate
item 5	D	37 (13.03)	-0.08		18.06	
	A	61 (21.48)	-0.22		19.44	
	B	99 (34.86)	0.10		35.42	
	C*	48 (16.90)	0.19	Reject	22.22	Moderate
item 6	D	69 (24.30)	-0.06		27.78	
	A	15 (5.28)	-0.13		6.25	
	B*	101 (35.56)	-0.17	Reject	33.33	Moderate
	C	151 (53.17)	0.33		62.50	
item 7	D	10 (3.52)	-0.07		3.47	
	A	6 (2.11)	-0.03		2.78	
	B	10 (3.52)	-0.03		4.17	
	C	9 (3.17)	-0.04		4.86	
item 8	D*	252 (88.73)	0.15	Reject	92.36	Easy
	A	7 (2.46)	-0.06		2.78	
	B*	189 (66.55)	0.18	Reject	72.92	Moderate
	C	36 (12.68)	-0.04		14.58	
item 9	D	47 (16.55)	-0.07		14.58	
	A	37 (13.03)	-0.10		11.81	
	B	4 (1.41)	-0.04		2.08	
	C*	227 (79.93)	0.25	Select	84.72	Easy
item 10	D	13 (4.58)	-0.08		6.94	
	A	60 (21.13)	-0.08		23.61	
	B*	117 (41.20)	0.49	Select	46.53	Moderate
	C	39 (13.73)	-0.19		11.11	
item 11	D	46 (16.20)	-0.10		17.36	
	A*	111 (39.08)	0.35	Select	45.14	Moderate
	B	108 (38.03)	-0.06		37.50	
	C	44 (15.49)	-0.24		18.75	
	D	12 (4.23)	-0.04		3.47	

* Correct Answer

Table 4: (Continued)

Item No.	Distracters	Choice frequency (%)	Discrimination Index	Status	Difficulty Index	Difficulty Status
item 12	A*	142 (50.00)	0.42	Select	59.72	Moderate
	B	63 (22.18)	-0.28		23.61	
	C	55 (19.37)	-0.07		15.97	
	D	18 (6.34)	-0.04		6.25	
item 13	A	114 (40.14)	-0.04		40.97	
	B*	95 (33.45)	0.18	Reject	35.42	Moderate
	C	29 (10.21)	-0.15		11.81	
	D	41 (14.44)	-0.01		17.36	
item 14	A	59 (20.77)	-0.08		27.78	
	B	50 (17.61)	-0.17		15.28	
	C	38 (13.38)	-0.10		13.19	
	D*	125 (44.01)	0.38	Select	47.92	Moderate
item 15	A*	240 (84.51)	0.29	Select	88.19	Easy
	B	6 (2.11)	-0.04		2.08	
	C	20 (7.04)	-0.13		9.03	
	D	11 (3.87)	-0.08		4.17	
item 16	A	27 (9.51)	-0.15		9.03	
	B*	212 (74.65)	0.43	Select	75.69	Moderate
	C	11 (3.87)	-0.11		5.56	
	D	28 (9.86)	-0.13		13.19	
item 17	A	39 (13.73)	-0.15		13.19	
	B*	218 (76.76)	0.36	Select	80.56	Easy
	C	6 (2.11)	-0.06		2.78	
	D	16 (5.63)	-0.14		8.33	
item 18	A	10 (3.52)	0.00		4.17	
	B	20 (7.04)	-0.11		8.33	
	C	40 (14.08)	-0.31		16.67	
	D*	208 (73.24)	0.47	Select	75.00	Moderate
item 19	A	14 (4.93)	-0.04		6.25	
	B	32 (11.27)	-0.17		15.28	
	C*	191 (67.25)	0.35	Select	71.53	Moderate
	D	35 (12.32)	-0.10		10.42	
item 20	A*	148 (52.11)	0.42	Select	56.94	Moderate
	B	20 (7.04)	-0.15		10.42	
	C	88 (30.99)	-0.18		29.86	
	D	20 (7.04)	-0.10		7.64	
item 21	A	37 (13.03)	-0.24		15.97	
	B	38 (13.38)	-0.10		10.42	
	C	8 (2.82)	-0.06		4.17	
	D*	194 (68.31)	0.40	Select	74.31	Moderate
item 22	A	57 (20.07)	-0.26		21.53	
	B*	179 (63.03)	0.49	Select	68.75	Moderate
	C	24 (8.45)	-0.18		9.03	
	D	20 (7.04)	-0.04		4.86	

* *Correct Answer*

Table 4: (Continued)

Item No.	Distracters	Choice frequency (%)	Discrimination index	Status	Difficulty Index	Difficulty Status
item 23	A	33 (11.62)	-0.28		13.89	
	B	15 (5.28)	-0.13		7.64	
	C	83 (29.23)	-0.07		28.47	
	D*	145 (51.06)	0.49	Select	53.47	Moderate
item 24	A*	199 (70.07)	0.31	Select	68.06	Moderate
	B	44 (15.49)	-0.33		20.83	
	C	17 (5.99)	0.03		8.33	
	D	14 (4.93)	-0.01		4.86	
item 25	A	76 (26.76)	0.00		29.17	
	B	43 (15.14)	0.01		14.58	
	C*	131 (46.13)	0.15	Reject	49.31	Moderate
	D	22 (7.75)	-0.10		10.42	
item 26	A	64 (22.54)	-0.36		22.22	
	B	43 (15.14)	-0.11		13.89	
	C*	143 (50.35)	0.56	Select	59.72	Moderate
	D	25 (8.80)	-0.06		8.33	
item 27	A	85 (29.93)	-0.13		34.03	
	B	84 (29.58)	-0.28		27.78	
	C*	88(30.99)	0.46	Select	39.58	Moderate
	D	22 (7.75)	-0.06		4.17	
item 28	A	8 (2.82)	-0.06		2.78	
	B	61 (21.48)	-0.32		22.92	
	C	10 (3.52)	-0.08		4.17	
	D*	195 (68.66)	0.51	Select	74.31	Moderate
item 29	A	4 (1.41)	-0.03		1.39	
	B	8 (2.82)	-0.07		3.47	
	C	13 (4.58)	-0.07		6.25	
	D*	252 (88.73)	0.24	Select	92.36	Easy
item 30	A	23 (8.10)	-0.15		10.42	
	B*	96 (33.80)	0.51	Select	39.58	Moderate
	C	91 (32.04)	-0.15		32.64	
	D	62 (21.83)	-0.24		20.14	
item 31	A	45 (15.85)	-0.19		15.28	
	B	50 (17.61)	-0.21		18.75	
	C	43 (15.14)	-0.18		15.97	
	D*	131 (46.13)	0.57	Select	52.08	Moderate
item 32	A	79 (27.82)	-0.17		26.39	
	B*	119 (41.90)	0.50	Select	51.39	Moderate
	C	73 (25.70)	-0.25		23.61	
	D	7 (2.46)	-0.06		2.78	
item 33	A*	262 (92.25)	0.15	Reject	97.92	Easy
	B	13 (4.58)	-0.07		4.86	
	C	3 (1.06)	-0.04		2.08	
	D	2 (0.70)	-0.03		1.39	

* Correct Answer

Table 4: (Continued)

Item No.	Distracters	Choice frequency (%)	Discrimination Index	Status	Difficulty Index	Difficulty Status
item 34	A	41(14.44)	-0.14		16.67	
	B	9 (3.17)	-0.06		2.78	
	C*	58 (20.42)	0.21	Select	22.92	Moderate
	D	170 (59.86)	0.00		62.50	
item 35	A*	82 (28.87)	0.13	Reject	36.81	Moderate
	B	48 (16.90)	0.06		20.83	
	C	32 (11.27)	0.01		11.81	
	D	108 (38.03)	-0.14		34.72	
item 36	A*	135 (47.54)	0.42	Select	54.17	Moderate
	B	83 (29.23)	-0.08		27.78	
	C	37 (13.03)	-0.22		13.89	
	D	19 (6.69)	-0.04		6.25	
item 37	A	67 (23.59)	-0.25		25.00	
	B	13 (4.58)	-0.13		7.64	
	C*	174 (61.27)	0.56	Select	63.89	Moderate
	D	20 (7.04)	-0.11		6.94	
item 38	A	113 (39.79)	-0.11		45.83	
	B	63 (22.18)	-0.08		22.22	
	C	31 (10.92)	-0.06		9.72	
	D	21 (7.39)	-0.01		6.25	
item 39	A	13 (4.58)	-0.03		4.17	
	B	28 (9.86)	-0.15		11.81	
	C	20 (7.04)	-0.22		11.11	
	D*	220 (77.46)	0.43	Select	78.47	Moderate
item 40	A	49 (17.25)	-0.38		20.14	
	B	13 (4.58)	-0.11		5.56	
	C	13 (4.58)	-0.08		4.17	
	D*	206 (72.54)	0.60	Select	75.69	Moderate
item 41	A	19 (6.69)	-0.07		7.64	
	B	23 (8.10)	-0.17		9.72	
	C	22 (7.75)	-0.13		7.64	
	D*	216 (76.06)	0.39	Select	80.56	Easy
item 42	A	12 (4.23)	-0.08		4.17	
	B	58 (20.42)	-0.19		22.22	
	C	45 (15.85)	-0.24		15.97	
	D*	159 (55.99)	0.56	Select	62.50	Moderate
item 43	A	28 (9.86)	-0.17		11.11	
	B	5 (1.76)	-0.01		2.08	
	C	3 (1.06)	-0.01		0.69	
	D*	243 (85.56)	0.22	Select	90.28	Easy
item 44	A	22 (7.75)	-0.19		9.72	
	B	38 (13.38)	-0.21		15.97	
	C*	209 (73.59)	0.46	Select	75.69	Moderate
	D	9 (3.17)	-0.04		3.47	

* *Correct Answer*

Table 4: (Continued)

Item No.	Distracters	Choice frequency (%)	Discrimination Index	Status	Difficulty Index	Difficulty Status
item 45	A	23 (8.10)	-0.08		11.11	
	B*	212 (74.65)	0.31	Select	77.78	Moderate
	C	17 (5.99)	-0.04		4.86	
	D	29 (10.21)	-0.15		11.81	
item 46	A	95 (33.45)	-0.21		34.03	
	B*	126 (44.37)	0.42	Select	47.22	Moderate
	C	50 (17.61)	-0.22		22.22	
	D	7 (2.46)	-0.01		2.08	
item 47	A	35 (12.32)	0.13		11.81	
	B*	104 (36.62)	0.01	Reject	38.19	Moderate
	C	118 (41.55)	0.01		45.14	
	D	25 (8.80)	-0.15		10.42	
item 48	A	25 (8.80)	-0.01		11.81	
	B	215 (75.70)	0.15		77.08	
	C*	29 (10.21)	-0.06	Reject	12.50	Difficult
	D	7 (2.46)	-0.04		2.08	
item 49	A	21 (7.39)	-0.04		9.03	
	B	54 (19.01)	-0.32		22.92	
	C	139 (48.94)	0.38		50.69	
	D*	58 (20.42)	-0.07	Reject	20.14	Moderate
item 50	A	55 (19.37)	-0.10		20.14	
	B	46 (16.20)	-0.11		18.06	
	C	45 (15.85)	-0.15		13.19	
	D*	131 (46.13)	0.33	Select	54.17	Moderate
item 51	A	50 (17.61)	-0.10		18.75	
	B*	183 (64.44)	0.35	Select	67.36	Moderate
	C	33 (11.62)	-0.25		12.50	
	D	16 (5.63)	0.01		7.64	
item 52	A*	53 (18.66)	0.35	Select	25.69	Moderate
	B	22 (7.75)	0.04		4.86	
	C	136 (47.89)	-0.10		49.31	
	D	63 (22.18)	-0.26		25.69	
item 53	A	21 (7.39)	-0.01		6.25	
	B	27 (9.51)	-0.10		11.81	
	C*	50 (17.61)	0.33	Select	25.00	Moderate
	D	178 (62.68)	-0.22		62.50	
item 54	A	7(2.46)	-0.07		3.47	
	B	81 (28.52)	-0.26		28.47	
	C*	176 (61.97)	0.46	Select	68.75	Moderate
	D	14 (4.93)	-0.11		5.56	
item 55	A	34 (11.97)	-0.01		11.81	
	B*	102 (35.92)	0.46	Select	46.53	Moderate
	C	64 (22.54)	-0.18		24.31	
	D	76 (26.76)	-0.24		22.92	

* Correct Answer

Table 4: (Continued)

Item No.	Distracters	Choice frequency (%)	Discrimination Index	Status	Difficulty Index	Difficulty Status
item 56	A	45 (15.85)	-0.35		18.75	
	B	16 (5.63)	-0.04		3.47	
	C	21 (7.39)	-0.14		8.33	
	D*	200 (70.42)	0.54	Select	75.69	Moderate
item 57	A	1 (0.35)	0.00		0.00	
	B	46 (16.20)	-0.08		16.67	
	C*	229 (80.63)	0.13	Reject	88.19	Easy
	D	6 (2.11)	-0.03		1.39	
item 58	A	5 (1.76)	-0.03		2.78	
	B	49 (17.25)	-0.29		17.36	
	C*	216 (76.06)	0.40	Select	81.25	Easy
	D	7 (2.46)	-0.06		2.78	
item 59	A	28(9.86)	-0.10		11.81	
	B	52 (18.31)	-0.11		18.06	
	C	42(14.79)	0.00		16.67	
	D*	142 (50.00)	0.19	Reject	54.17	Moderate
item 60	A	47 (16.55)	-0.11		15.28	
	B	40 (14.08)	-0.26		15.97	
	C*	143 (50.35)	0.56	Select	54.17	Moderate
	D	39 (13.73)	-0.14		15.28	
item 61	A	71 (25.00)	-0.28		23.61	
	B	7 (2.46)	-0.10		4.86	
	C*	197 (69.37)	0.43	Select	75.69	Moderate
	D	4 (1.41)	-0.04		2.08	
item 62	A	123 (43.31)	0.22		51.39	
	B*	72 (25.35)	0.00	Reject	25.00	Moderate
	C	52 (18.31)	-0.13		17.36	
	D	27 (9.51)	-0.08		11.11	
item 63	A	55 (19.37)	0.15		18.75	
	B*	145 (51.06)	0.07	Reject	61.81	Moderate
	C	39 (13.73)	-0.04		10.42	
	D	36 (12.68)	-0.18		13.19	
item 64	A	32 (11.27)	0.07		10.42	
	B	108 (38.03)	-0.10		38.19	
	C*	120 (42.25)	0.07	Reject	49.31	Moderate
	D	19 (6.69)	-0.01		7.64	
item 65	A	55 (19.37)	-0.10		20.14	
	B	53 (18.66)	-0.06		19.44	
	C*	122 (42.96)	0.42	Select	44.44	Moderate
	D	43 (15.14)	-0.25		20.83	
item 66	A	26 (9.15)	-0.15		7.64	
	B	121 (42.61)	0.07		49.31	
	C	35 (12.32)	-0.15		14.58	
	D*	97 (34.15)	0.22	Select	33.33	Moderate

* *Correct Answer*

Table 4: (Continued)

Item No.	Distracters	Choice frequency (%)	Discrimination Index	Status	Difficulty Index	Difficulty Status
item 67	A	67 (23.59)	0.11		25.00	
	B*	176 (61.97)	0.19	Reject	65.28	Moderate
	C	27 (9.51)	-0.21		10.42	
	D	12 (4.23)	-0.10		6.25	
item 68	A*	93 (32.75)	0.57	Select	38.19	Moderate
	B	61 (21.48)	0.01		20.14	
	C	8 (2.82)	-0.01		2.08	
	D	114 (40.14)	-0.56		44.44	
item 69	A	11 (3.87)	-0.07		4.86	
	B	34 (11.97)	-0.06		11.11	
	C*	169 (59.51)	0.15	Reject	65.97	Moderate
	D	62 (21.83)	-0.06		20.83	
item 70	A	26 (9.15)	-0.28		13.89	
	B*	233 (82.04)	0.36	Select	84.72	Easy
	C	8 (2.82)	-0.03		2.78	
	D	12 (4.23)	-0.03		4.17	
item 71	A*	105 (36.97)	0.43	Select	45.14	Moderate
	B	69(24.30)	-0.19		25.00	
	C	62(21.83)	-0.19		23.61	
	D	31 (10.92)	0.00		9.72	
item 72	A	10 (3.52)	0.00		2.78	
	B	123 (43.31)	-0.03		43.06	
	C	47 (16.55)	-0.17		19.44	
	D*	85 (29.93)	0.19	Reject	36.11	Moderate
item 73	A	15 (5.28)	-0.11		5.56	
	B	70 (24.65)	-0.35		27.08	
	C	18 (6.34)	-0.14		8.33	
	D*	175 (61.62)	0.63	Select	64.58	Moderate
item 74	A	92 (32.39)	-0.06		34.72	
	B*	107 (37.68)	0.22	Select	38.89	Moderate
	C	51(17.96)	-0.14		22.22	
	D	20 (7.04)	-0.04		7.64	
item 75	A*	101 (35.56)	0.17	Reject	43.06	Moderate
	B	104 (36.62)	0.13		34.03	
	C	23 (8.10)	-0.06		6.94	
	D	43(15.14)	-0.25		19.44	
item 76	A*	157 (55.28)	0.22	Select	58.33	Moderate
	B	64 (22.54)	-0.03		19.44	
	C	26 (9.15)	-0.01		11.81	
	D	23 (8.10)	-0.13		10.42	
item 77	A*	134 (47.18)	0.40	Select	49.31	Moderate
	B	28 (9.86)	-0.10		13.19	
	C	47 (16.55)	-0.07		17.36	
	D	59 (20.77)	-0.17		22.22	

* Correct Answer

Table 4: (Continued)

Item No.	Distracters	Choice frequency (%)	Discrimination Index	Status	Difficulty Index	Difficulty Status
item 78	A	65 (22.89)	-0.32		28.47	
	B	49 (17.25)	-0.10		15.97	
	C	56 (19.72)	-0.01		17.36	
	D*	103 (36.27)	0.46	Select	39.58	Moderate
item 79	A*	71 (25.00)	0.31	Select	33.33	Moderate
	B	57 (20.07)	-0.19		22.22	
	C	30 (10.56)	-0.15		10.42	
	D	118 (41.55)	0.03		38.89	
item 80	A	42 (14.79)	-0.01		14.58	
	B	91 (32.04)	-0.21		35.42	
	C*	93 (32.75)	0.17	Reject	40.28	Moderate
	D	40 (14.08)	0.04		11.81	
item 81	A*	68 (23.94)	0.44	Select	30.56	Moderate
	B	98 (34.51)	-0.13		25.69	
	C	87 (30.63)	-0.07		35.42	
	D	26 (9.15)	-0.24		13.19	
item 82	A	74 (26.06)	0.01		24.31	
	B*	90 (31.69)	0.38	Select	38.19	Moderate
	C	79 (27.82)	-0.28		30.56	
	D	33 (11.62)	-0.11		11.11	
item 83	A*	145 (51.06)	0.33	Select	58.33	Moderate
	B	33 (11.62)	-0.10		10.42	
	C	82 (28.87)	-0.13		28.47	
	D	13 (4.58)	-0.08		5.56	
item 84	A	76 (26.76)	-0.21		27.08	
	B*	162 (57.04)	0.36	Select	63.89	Moderate
	C	26 (9.15)	-0.03		8.33	
	D	8 (2.82)	-0.07	Reject	3.47	
item 85	A	50 (17.61)	-0.19		16.67	
	B	90 (31.69)	0.06		30.56	
	C*	93 (32.75)	0.14	Select	43.06	Moderate
	D	42 (14.79)	0.03		12.50	
item 86	A	35 (12.32)	-0.13		10.42	
	B	27 (9.51)	-0.07		10.42	
	C	51 (17.96)	-0.10		15.97	
	D*	162 (57.04)	0.36	Select	65.28	Moderate
item 87	A	22 (7.75)	-0.10		9.03	
	B	95 (33.45)	-0.22		33.33	
	C	49 (17.25)	-0.18		17.36	
	D*	111 (39.08)	0.56	Select	43.06	Moderate
item 88	A	3 (1.06)	-0.03		1.39	
	B*	252 (88.73)	0.19	Reject	90.28	Easy
	C	8 (2.82)	-0.07		4.86	
	D	11 (3.87)	-0.07		4.86	

* *Correct Answer*

Table 4: (Continued)

Item No.	Distracters	Choice frequency (%)	Discrimination Index	Status	Difficulty Index	Difficulty Status
item 89	A*	128 (45.07)	0.58	Select	47.22	Moderate
	B	26 (9.15)	-0.10		7.64	
	C	96 (33.80)	-0.29		36.81	
	D	25 (8.80)	-0.18		10.42	
item 90	A	66 (23.24)	-0.15		24.31	
	B	22 (7.75)	-0.13		7.64	
	C*	168 (59.15)	0.44	Select	62.50	Moderate
	D	21 (7.39)	-0.14		8.33	
item 91	A	88 (30.99)	-0.03		31.94	
	B	21 (7.39)	-0.14		8.33	
	C*	142 (50.00)	0.24	Select	52.08	Moderate
	D	20 (7.04)	-0.04		7.64	
item 92	A	37 (13.03)	0.00		9.72	
	B	131 (46.13)	0.47		47.22	
	C	77 (27.11)	-0.38		32.64	
	D*	28 (9.86)	-0.10	Reject	11.81	Difficult
item 93	A	111 (39.08)	0.07		40.97	
	B	66 (23.24)	-0.11		25.00	
	C*	60 (21.13)	0.13	Reject	24.31	Moderate
	D	36 (12.68)	-0.06		12.50	
item 94	A	38 (13.38)	-0.04		13.19	
	B	49 (17.25)	-0.03		12.50	
	C*	96 (33.80)	0.32	Select	39.58	Moderate
	D	92 (32.39)	-0.22		37.50	
item 95	A	19 (6.69)	-0.04		7.64	
	B	128 (45.07)	-0.08		45.83	
	C	44 (15.49)	-0.17		15.28	
	D*	82 (28.87)	0.29	Select	34.03	Moderate
item 96	A*	133 (46.83)	0.31	Select	47.22	Moderate
	B	40 (14.08)	-0.11		15.28	
	C	59 (20.77)	-0.11		23.61	
	D	35 (12.32)	-0.06		13.89	
item 97	A	50 (17.61)	0.03		19.44	
	B*	150 (52.82)	-0.01	Reject	53.47	Moderate
	C	53 (18.66)	-0.04		18.75	
	D	18 (6.34)	0.04		9.03	
item 98	A	18 (6.34)	-0.06		5.56	
	B	26 (9.15)	-0.03		8.33	
	C*	208 (73.24)	0.19	Reject	79.17	Moderate
	D	17 (5.99)	-0.10		6.25	
item 99	A	93 (32.75)	-0.17		29.17	
	B	41 (14.44)	-0.07		11.81	
	C*	103 (36.27)	0.46	Select	46.53	Moderate
	D	28 (9.86)	-0.13		10.42	
item 100	A	74 (26.06)	-0.06		25.00	
	B	80 (28.17)	-0.21		27.08	
	C	50 (17.61)	-0.01		20.14	
	D*	65 (22.89)	0.32	Select	27.08	Moderate

* Correct Answer

APPENDIX E**Table 5**
Summary of Item Discrimination index

Sr. No.	Discrimination index	No. of Items	Item no.
1	Less than 0.20	27	4, 5, 6, 7, 8, 13, 25, 33, 35, 47, 48, 49, 57, 59, 62, 63, 64, 67, 69, 72, 75, 80, 85, 88, 92, 93, 97,
2	Greater than 0.80	0	Null
3	Accepted range 0.20 to 0.80	72	Rest of Items

APPENDIX F**Table 6**
Summary of Difficulty Index

Sr. No.	Difficulty index	No. of Items	Item no.
1	Less than 20%	2	48,92
2	Greater than 80%	11	1, 2, 7, 9, 15, 29, 33, 43, 57, 70, 88
3	Accepted range 20% to 80%	86	Rest of items

APPENDIX G**Table 7**
Items Rejected on the Basis of D and P

Items rejected on the basis of D	Items rejected on the basis of P	Items rejected on the basis of D and P
4, 5 ,6, 7, 8, 13, 25, 33, 35,47,48,49,57,59,62, 63, 64, 67, 69, 72,75, 80,84, 88, 92, 93, 97, 98	1, 2, 7, 9, 15, 29, 33,43,57,70, 88	7, 33, 48, 57, 88, 92

APPENDIX H

Table 8: Correction of Items

No.	Item no.	Alternatives	Difficulty Index
1	item 34	A	16.67
		B	2.78
		C*	22.92
		D	62.50
2	item 52	A*	25.69
		B	4.86
		C	49.31
		D	25.69
3	item 53	A	6.25
		B	11.81
		C*	25.00
		D	62.50
4	item 66	A	7.64
		B	49.31
		C	14.58
		D*	33.33
5	item 68	A*	38.19
		B	20.14
		C	2.08
		D	44.44
6	item 79	A*	33.33
		B	22.22
		C	10.42
		D	38.89
7	item 81	A*	30.56
		B	25.69
		C	35.42
		D	13.19
8	item 95	A	7.64
		B	45.83
		C	15.28
		D*	34.03
9	item 100	A	25.00
		B	27.08
		C	20.14
		D*	27.08

APPENDIX I

Table 9: Application and Analysis of Items through Rasch Model

No. of Items: 100 (L); No. of Students: 280(N)

Item No. I	Item score Si	Proportion		Logit incorrect $X_i = \ln\left(\frac{1-p_i}{p_i}\right)$	Initial item calibration $D_i = X_i - M$	Sample spread expansion Factor (y)	item final calibration $d_i = D_i \cdot y$
		Correct $P_i = \frac{S_i}{N}$	Incorrect $1-p_i$				
33	258	0.92	0.08	-2.46	-2.40	1.03	-2.47
88	250	0.89	0.11	-2.12	-2.06	1.03	-2.12
7	249	0.89	0.11	-2.08	-2.02	1.03	-2.08
29	248	0.89	0.11	-2.05	-1.98	1.03	-2.04
2	242	0.86	0.14	-1.85	-1.79	1.03	-1.84
43	240	0.86	0.14	-1.79	-1.73	1.03	-1.78
15	239	0.85	0.15	-1.76	-1.70	1.03	-1.75
70	229	0.82	0.18	-1.50	-1.44	1.03	-1.48
57	225	0.80	0.20	-1.41	-1.34	1.03	-1.38
9	225	0.80	0.20	-1.41	-1.34	1.03	-1.38
39	216	0.77	0.23	-1.22	-1.15	1.03	-1.19
17	216	0.77	0.23	-1.22	-1.15	1.03	-1.19
41	214	0.76	0.24	-1.18	-1.11	1.03	-1.14
1	213	0.76	0.24	-1.16	-1.09	1.03	-1.12
58	212	0.76	0.24	-1.14	-1.07	1.03	-1.10
45	210	0.75	0.25	-1.10	-1.03	1.03	-1.06
16	210	0.75	0.25	-1.10	-1.03	1.03	-1.06
44	206	0.74	0.26	-1.02	-0.96	1.03	-0.99
18	206	0.74	0.26	-1.02	-0.96	1.03	-0.99
98	205	0.73	0.27	-1.01	-0.94	1.03	-0.97
40	202	0.72	0.28	-0.95	-0.89	1.03	-0.91
56	196	0.70	0.30	-0.85	-0.78	1.03	-0.81
24	196	0.70	0.30	-0.85	-0.78	1.03	-0.81
61	194	0.69	0.31	-0.81	-0.75	1.03	-0.77
28	194	0.69	0.31	-0.81	-0.75	1.03	-0.77
21	193	0.69	0.31	-0.80	-0.73	1.03	-0.75
19	189	0.68	0.33	-0.73	-0.67	1.03	-0.69
8	187	0.67	0.33	-0.70	-0.63	1.03	-0.65
51	180	0.64	0.36	-0.59	-0.52	1.03	-0.54
22	176	0.63	0.37	-0.53	-0.46	1.03	-0.48
67	174	0.62	0.38	-0.50	-0.43	1.03	-0.44
73	173	0.62	0.38	-0.48	-0.42	1.03	-0.43
54	173	0.62	0.38	-0.48	-0.42	1.03	-0.43

37	172	0.61	0.39	-0.47	-0.40	1.03	-0.41
90	167	0.60	0.40	-0.39	-0.33	1.03	-0.34
69	167	0.60	0.40	-0.39	-0.33		-0.34
84	160	0.57	0.43	-0.29	-0.22	1.03	-0.23
86	159	0.57	0.43	-0.27	-0.21	1.03	-0.21
76	156	0.56	0.44	-0.23	-0.16	1.03	-0.17
42	156	0.56	0.44	-0.23	-0.16	1.03	-0.17
97	148	0.53	0.47	-0.11	-0.05	1.03	-0.05
20	148	0.53	0.47	-0.11	-0.05	1.03	-0.05
63	143	0.51	0.49	-0.04	0.02	1.03	0.02
23	143	0.51	0.49	-0.04	0.02	1.03	0.02
83	142	0.51	0.49	-0.03	0.04	1.03	0.04
60	142	0.51	0.49	-0.03	0.04	1.03	0.04
59	142	0.51	0.49	-0.03	0.04	1.03	0.04
26	142	0.51	0.49	-0.03	0.04	1.03	0.04
12	141	0.50	0.50	-0.01	0.05	1.03	0.05
91	139	0.50	0.50	0.01	0.08	1.03	0.08
4	139	0.50	0.50	0.01	0.08	1.03	0.08
77	133	0.48	0.53	0.10	0.17	1.03	0.17
36	133	0.48	0.53	0.10	0.17	1.03	0.17
96	131	0.47	0.53	0.13	0.19	1.03	0.20
50	130	0.46	0.54	0.14	0.21	1.03	0.21
31	130	0.46	0.54	0.14	0.21	1.03	0.21
25	130	0.46	0.54	0.14	0.21	1.03	0.21
3	129	0.46	0.54	0.16	0.22	1.03	0.23
89	127	0.45	0.55	0.19	0.25	1.03	0.26
46	123	0.44	0.56	0.24	0.31	1.03	0.32
14	122	0.44	0.56	0.26	0.32	1.03	0.33
65	119	0.43	0.58	0.30	0.37	1.03	0.38
64	118	0.42	0.58	0.32	0.38	1.03	0.39
32	118	0.42	0.58	0.32	0.38	1.03	0.39
10	115	0.41	0.59	0.36	0.43	1.03	0.44
11	111	0.40	0.60	0.42	0.49	1.03	0.50
87	110	0.39	0.61	0.44	0.50	1.03	0.52
74	106	0.38	0.62	0.50	0.56	1.03	0.58
71	104	0.37	0.63	0.53	0.59	1.03	0.61
47	102	0.36	0.64	0.56	0.62	1.03	0.64
75	101	0.36	0.64	0.57	0.64	1.03	0.66
42	156	0.56	0.44	-0.23	-0.16	1.03	-0.17
97	148	0.53	0.47	-0.11	-0.05	1.03	-0.05
20	148	0.53	0.47	-0.11	-0.05	1.03	-0.05
63	143	0.51	0.49	-0.04	0.02	1.03	0.02

6	101	0.36	0.64	0.57	0.64	1.03	0.66
99	100	0.36	0.64	0.59	0.65	1.03	0.67
55	100	0.36	0.64	0.59	0.65	1.03	0.67
78	99	0.35	0.65	0.60	0.67	1.03	0.69
66	96	0.34	0.66	0.65	0.72	1.03	0.74
30	95	0.34	0.66	0.67	0.73	1.03	0.75
13	95	0.34	0.66	0.67	0.73	1.03	0.75
94	93	0.33	0.67	0.70	0.76	1.03	0.79
80	93	0.33	0.67	0.70	0.76	1.03	0.79
85	92	0.33	0.67	0.71	0.78	1.03	0.80
68	90	0.32	0.68	0.75	0.81	1.03	0.84
82	89	0.32	0.68	0.76	0.83	1.03	0.85
27	87	0.31	0.69	0.80	0.86	1.03	0.89
72	85	0.30	0.70	0.83	0.90	1.03	0.92
35	81	0.29	0.71	0.90	0.96	1.03	0.99
95	80	0.29	0.71	0.92	0.98	1.03	1.01
62	72	0.26	0.74	1.06	1.13	1.03	1.16
79	70	0.25	0.75	1.10	1.16	1.03	1.20
100	65	0.23	0.77	1.20	1.26	1.03	1.30
81	65	0.23	0.77	1.20	1.26	1.03	1.30
93	60	0.21	0.79	1.30	1.36	1.03	1.41
49	58	0.21	0.79	1.34	1.41	1.03	1.45
34	58	0.21	0.79	1.34	1.41	1.03	1.45
52	50	0.18	0.82	1.53	1.59	1.03	1.64
53	49	0.18	0.83	1.55	1.62	1.03	1.66
5	48	0.17	0.83	1.58	1.64	1.03	1.69
48	29	0.10	0.90	2.16	2.22	1.03	2.29
92	28	0.10	0.90	2.20	2.26	1.03	2.33

M= -0.06 U=0.93

APPENDIX J

Table 10: Prox Person Measurement

Total no. of items: 100 (L)

Total no. of Students: 280 (N)

Person frequency	Blocks	Possible score	Proportion		logit correct $vr=\ln$ $(Pr/1-Pr)$	Initial measurement $Br=Vr$	Test width expansion factor x	Final measurement $br=x.br$
			Correct $Pr=r/L$	Incorrect 1-Pr				
0	B1	1	0.01	0.99	-4.60	-4.60	1.03	-4.73
0	B2	2	0.02	0.98	-3.89	-3.89	1.03	-4.01
0	B3	3	0.03	0.97	-3.48	-3.48	1.03	-3.58
0	B4	4	0.04	0.96	-3.18	-3.18	1.03	-3.27
0	B5	5	0.05	0.95	-2.94	-2.94	1.03	-3.03
0	B6	6	0.06	0.94	-2.75	-2.75	1.03	-2.83
0	B7	7	0.07	0.93	-2.59	-2.59	1.03	-2.66
0	B8	8	0.08	0.92	-2.44	-2.44	1.03	-2.52
0	B9	9	0.09	0.91	-2.31	-2.31	1.03	-2.38
0	B10	10	0.1	0.9	-2.20	-2.20	1.03	-2.26
0	B11	11	0.11	0.89	-2.09	-2.09	1.03	-2.15
0	B12	12	0.12	0.88	-1.99	-1.99	1.03	-2.05
0	B13	13	0.13	0.87	-1.90	-1.90	1.03	-1.96
0	B14	14	0.14	0.86	-1.82	-1.82	1.03	-1.87
0	B15	15	0.15	0.85	-1.73	-1.73	1.03	-1.79
0	B16	16	0.16	0.84	-1.66	-1.66	1.03	-1.71
0	B17	17	0.17	0.83	-1.59	-1.59	1.03	-1.63
1	B18	18	0.18	0.82	-1.52	-1.52	1.03	-1.56
0	B19	19	0.19	0.81	-1.45	-1.45	1.03	-1.49
0	B20	20	0.2	0.8	-1.39	-1.39	1.03	-1.43
0	B21	21	0.21	0.79	-1.32	-1.32	1.03	-1.36
0	B22	22	0.22	0.78	-1.27	-1.27	1.03	-1.30
1	B23	23	0.23	0.77	-1.21	-1.21	1.03	-1.24
0	B24	24	0.24	0.76	-1.15	-1.15	1.03	-1.19
0	B25	25	0.25	0.75	-1.10	-1.10	1.03	-1.13
0	B26	26	0.26	0.74	-1.05	-1.05	1.03	-1.08
1	B27	27	0.27	0.73	-0.99	-0.99	1.03	-1.02
2	B28	28	0.28	0.72	-0.94	-0.94	1.03	-0.97
2	B29	29	0.29	0.71	-0.90	-0.90	1.03	-0.92
2	B30	30	0.3	0.7	-0.85	-0.85	1.03	-0.87
1	B31	31	0.31	0.69	-0.80	-0.80	1.03	-0.82
2	B32	32	0.32	0.68	-0.75	-0.75	1.03	-0.78
4	B33	33	0.33	0.67	-0.71	-0.71	1.03	-0.73
5	B34	34	0.34	0.66	-0.66	-0.66	1.03	-0.68

Table 10 (Continued)

Person frequency	Blocks	Possible score	Proportion		logit correct $vr=\ln$ $(Pr/1-Pr)$	Initial measurement $Br=Vr$	Test width expansion factor x	Final measurements $br=x.br$
			Correct $Pr=r/L$	Incorrect $1-Pr$				
4	B35	35	0.35	0.65	-0.62	-0.62	1.03	-0.64
6	B36	36	0.36	0.64	-0.58	-0.58	1.03	-0.59
4	B37	37	0.37	0.63	-0.53	-0.53	1.03	-0.55
9	B38	38	0.38	0.62	-0.49	-0.49	1.03	-0.50
2	B39	39	0.39	0.61	-0.45	-0.45	1.03	-0.46
7	B40	40	0.4	0.6	-0.41	-0.41	1.03	-0.42
9	B41	41	0.41	0.59	-0.36	-0.36	1.03	-0.37
9	B42	42	0.42	0.58	-0.32	-0.32	1.03	-0.33
13	B43	43	0.43	0.57	-0.28	-0.28	1.03	-0.29
13	B44	44	0.44	0.56	-0.24	-0.24	1.03	-0.25
7	B45	45	0.45	0.55	-0.20	-0.20	1.03	-0.21
11	B46	46	0.46	0.54	-0.16	-0.16	1.03	-0.17
12	B47	47	0.47	0.53	-0.12	-0.12	1.03	-0.12
9	B48	48	0.48	0.52	-0.08	-0.08	1.03	-0.08
8	B49	49	0.49	0.51	-0.04	-0.04	1.03	-0.04
6	B50	50	0.5	0.5	0.00	0.00	1.03	0.00
6	B51	51	0.51	0.49	0.04	0.04	1.03	0.04
11	B52	52	0.52	0.48	0.08	0.08	1.03	0.08
9	B53	53	0.53	0.47	0.12	0.12	1.03	0.12
12	B54	54	0.54	0.46	0.16	0.16	1.03	0.17
8	B55	55	0.55	0.45	0.20	0.20	1.03	0.21
2	B56	56	0.56	0.44	0.24	0.24	1.03	0.25
14	B57	57	0.57	0.43	0.28	0.28	1.03	0.29
5	B58	58	0.58	0.42	0.32	0.32	1.03	0.33
5	B59	59	0.59	0.41	0.36	0.36	1.03	0.37
5	B60	60	0.6	0.4	0.41	0.41	1.03	0.42
3	B61	61	0.61	0.39	0.45	0.45	1.03	0.46
6	B62	62	0.62	0.38	0.49	0.49	1.03	0.50
5	B63	63	0.63	0.37	0.53	0.53	1.03	0.55
3	B64	64	0.64	0.36	0.58	0.58	1.03	0.59
5	B65	65	0.65	0.35	0.62	0.62	1.03	0.64
1	B66	66	0.66	0.34	0.66	0.66	1.03	0.68
2	B67	67	0.67	0.33	0.71	0.71	1.03	0.73
1	B68	68	0.68	0.32	0.75	0.75	1.03	0.78
1	B69	69	0.69	0.31	0.80	0.80	1.03	0.82
5	B70	70	0.7	0.3	0.85	0.85	1.03	0.87
2	B71	71	0.71	0.29	0.90	0.90	1.03	0.92
1	B72	72	0.72	0.28	0.94	0.94	1.03	0.97
2	B73	73	0.73	0.27	0.99	0.99	1.03	1.02
1	B74	74	0.74	0.26	1.05	1.05	1.03	1.08
3	B75	75	0.75	0.25	1.10	1.10	1.03	1.13
3	B76	76	0.76	0.24	1.15	1.15	1.03	1.19

V=0.29

Table 10 (Continued)

Person frequency	Blocks	Possible score	Proportion		logit correct $v_r=nl$ (Pr/1-Pr)	Initial measurement $B_r=V_r$	Test width expansion factor x	Final measurements $br=x.br$
			Correct $Pr=r/L$	Incorrect $1-Pr$				
0	B77	77	0.77	0.23	1.21	1.21	1.03	1.24
1	B78	78	0.78	0.22	1.27	1.27	1.03	1.30
3	B79	79	0.79	0.21	1.32	1.32	1.03	1.36
1	B80	80	0.8	0.2	1.39	1.39	1.03	1.43
0	B81	81	0.81	0.19	1.45	1.45	1.03	1.49
0	B82	82	0.82	0.18	1.52	1.52	1.03	1.56
0	B83	83	0.83	0.17	1.59	1.59	1.03	1.63
2	B84	84	0.84	0.16	1.66	1.66	1.03	1.71
1	B85	85	0.85	0.15	1.73	1.73	1.03	1.79
0	B86	86	0.86	0.14	1.82	1.82	1.03	1.87
0	B87	87	0.87	0.13	1.90	1.90	1.03	1.96
0	B88	88	0.88	0.12	1.99	1.99	1.03	2.05
1	B89	89	0.89	0.11	2.09	2.09	1.03	2.15
0	B90	90	0.9	0.1	2.20	2.20	1.03	2.26
0	B91	91	0.91	0.09	2.31	2.31	1.03	2.38
0	B92	92	0.92	0.08	2.44	2.44	1.03	2.52
0	B93	93	0.93	0.07	2.59	2.59	1.03	2.66
0	B94	94	0.94	0.06	2.75	2.75	1.03	2.83
0	B95	95	0.95	0.05	2.94	2.94	1.03	3.03
0	B96	96	0.96	0.04	3.18	3.18	1.03	3.27
0	B97	97	0.97	0.03	3.48	3.48	1.03	3.58
0	B98	98	0.98	0.02	3.89	3.89	1.03	4.01
0	B99	99	0.99	0.01	4.60	4.60	1.03	4.73

V=0.29

APPENDIX K**Table 11: Item Characteristic Curve**

Person ability ↓	difficulty level →	-2.04	0.67	2.33
		Probability values		
-4.73		0.06	0.00	0.00
-3.03		0.27	0.02	0.00
-2.26		0.44	0.05	0.01
-1.79		0.56	0.08	0.02
-1.08		0.72	0.15	0.03
-0.87		0.76	0.18	0.04
-0.33		0.85	0.27	0.07
-0.04		0.88	0.33	0.09
0.55		0.93	0.47	0.14
0.87		0.95	0.55	0.19
1.43		0.97	0.68	0.29
1.96		0.98	0.78	0.41
2.38		0.99	0.85	0.51
2.66		0.99	0.88	0.58
3.03		0.99	0.91	0.67
4.73		1.00	0.98	0.92

APPENDIX L

Table 12: Person Characteristic Curve

Item Difficulty ↓	Person Ability →	-2.15	0.17	1.96
		Probability values		
-2.47		0.58	0.93	0.99
-1.84		0.42	0.88	0.98
-1.06		0.25	0.77	0.95
-1.48		0.34	0.84	0.97
-1.12		0.26	0.78	0.96
-0.81		0.21	0.73	0.94
-0.34		0.14	0.62	0.91
-0.05		0.11	0.55	0.88
0.05		0.10	0.53	0.87
0.33		0.08	0.46	0.84
0.80		0.05	0.35	0.76
1.16		0.04	0.27	0.69
1.45		0.03	0.22	0.62
1.69		0.02	0.18	0.57
2.33		0.01	0.10	0.41