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Performance Indicator on Parallel Circuit Conceptual Test (Pccut): A Fit Statistic Approaches

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ABSTRACT

The performance of science students in local Higher Education Institutions (HEI) has received vast interest from researchers and academicians. There is substantial research evidence leading to the fact that many of these students undergoing degree courses do not possess a robust conceptual understanding of fundamental phenomena in science subject especially electricity. In fact, there is limited means of identifying their basic understanding in this particular branch of Physics. Hence, this research aims to assess the students' conceptual understanding in electricity via an instrument named Parallel Circuit Conceptual Test (PCCUT). Rasch analysis has been used to assess and measure the students' performance. Hence, from the results obtained, an academic performance indicator was created to display the level of conceptual understanding that the students have on the topic of electricity particularly parallel circuitry. Similar performance indicator could be generated for other area of sciences in order to identify the students' area of strength and weaknesses.

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INTRODUCTION

The performance of science students in local Higher Education Institutions (HEI) has received vast interest from researchers and academicians. There is substantial research evidence leading to the fact that many of these students undergoing degree courses do not possess a robust conceptual understanding of fundamental phenomena in science subject especially electricity (Bledsoe, 2007; Miokovic, Gnazberger & Radolic, 2012). In fact, there is limited means of identifying their basic understanding in this particular branch of Physics. Hence, this research aims to assess the students' academic performance in electricity via an instrument named Parallel Circuit Conceptual Test (PCCUT). Rasch Analysis has been used to assess and measure the students' performance. Hence, from the results obtained, an academic performance indicator was created to display the level of conceptual understanding that the students have on the topic of electricity particularly parallel circuitry.

The Rasch Measurement Model is a formulation that stipulates the relationship between a person and an item based on a mutual latent trait. To be more precise, it is able to predict the likelihood of a person of a given capability to correctly respond to an item of a certain difficulty level. The probability of success depends on the difference between the ability of the person and the difficulty of the item.

The Rasch Measurement Model is based on two fundamental theorems which say that:

- A person who is more capable has a greater likelihood of correctly answering all the items given.
- An easier item is more likely to be answered correctly by all persons.

In other words, the Rasch Model assumes that the item difficulty is the attribute that is influencing the person responses while the person ability is the attribute that is influencing the item difficulty estimates (Linacre, 1999).

Fit statistics by Rasch Analysis enable the researchers to see whether the data they are using is feasible; specifically higher ability students should be more likely to answer items of greater difficulty correctly than the lower ability students (Bradley, Cunningham & Sampson, 2007). It includes the outfit and infit (mean square and standardized values) of the persons and items. According to Green and Frantoum (2002), the term fit refers to "infit" (weighted by the distance between the person position and item difficulty) and "outfit" (an unweighted

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measure). If the data fit the Rasch model, then the expected values of the mean square and the standardized fit indices are 1.0 and 0.0 respectively. Most of the times, outfit is more sensitive to extreme responses compared to the infit.

Since Rasch takes into account the relationship between the person's capability and item difficulty, hence it is desirable to look at the person fit as well as the item fit. The Person fit refers to an index which signifies the responses of an individual (Bond & Fox, 2007). An irregular or erratic response could be a sign of a misfit. Similarly, an item fit refers to an index which implies the functionality of the item (Wright, 1997). A misfit item means that the particular item is either too difficult or too easy for the respondent; or it could mean that the item is not really testing on the desired latent trait. There are means of checking for quality control in Rasch.
In order to verify for fit and misfit items or persons, the following criteria must be satisfied:

- Point Measure Correlation: $0.32 < x < 0.8$
- Outfit Mean Square, $0.5 < y < 1.5$
- Outfit Z standard , $-2.0 < Z < +2.0$

Sample and instrument:

The samples for this research were selected via cluster random sampling where a selected group of science students studying in a local Malaysian university was identified. A group of 102 students of mixed academic ability from weak to excellent, from different science background and genders were chosen.

PCCUT was designed to test the students' understanding on the topic of basic parallel resistors. The instrument was divided in to six sections which basically are the major problems encountered by most students. The six sections are:

- Section 1 - Meaning of the term parallel
- Section 2 - Practical Knowledge of Current
- Section 3 - Practical Knowledge of voltage in parallel circuit
- Section 4 - Practical Knowledge of Resistance
- Section 5 - Practical Knowledge of circuit connection: parallel and series
- Section 6 - Mental Model

Methodology:

The questionnaires of 34 items were administered to the students and the data were collected. The analysis of the data was done using Rasch Analysis Software (WINSTEPS 3.71.0.1). The idea of the test is to establish a profile of the students in the area of basic parallel resistors, hence providing an academic performance indicator for the students and educators to identify the students' basic conceptual understanding on the topic of parallel circuit in electricity. These indicators enable the individuals to identify their area of strength and weaknesses so that strategies could be planned to enhanced students' performance in this area

Result:

From Table 1, a total data point of 3468 evolved from 102 respondents on the 34 items analyzed (34 x 102 =3468). It produces a Chi–square value of 3143.65 with 3333 degrees of freedom (p= 0.9908). This means that the overall fit to the measurement is good. In terms of the item reliability, the final version of PCCUT produced 'excellent' item reliability (Fisher, 2007) of +0.97 logit. It indicates that the probability of the difficulty levels of every item remaining exactly the same if the instrument were given to a different group of science students is high. Hence, the instrument holds an "excellent" position of not being dependent on the respondents.

Table 1: Summary Statistics for 34 items.

	Total score	Count	Measure	Model Error	Infit		Outfit	
					MnSq	Zstd	MnSq	Zstd
Mean	47.4	102.0	0.00	0.30	1.00	0.0	0.95	-0.1
SD	26.6	0.0	1.87	0.15	0.15	1.4	0.31	1.5
Max	99.0	102.0	5.06	1.02	1.35	3.8	1.83	5.0
Min	1.0	102.0	-4.18	0.22	0.75	-2.8	0.42	-2.6
Real RMSE .34 True SD 1.84 Separation 5.37 Item Reliability .97 S.E. OF Item MEAN = .33 3468 Data points. Log-likelihood Chi-Square: 3143.65 with 3333 d.f. (P=.9908)								

From Table 2, the Person reliability is identified as 'good' at +0.81 by Fisher (2007). However, the Cronbach Alpha (KR-20) Person Raw score test reliability is high at +0.82. is with the reliability at +0.82, if a similar set of instrument measuring the conceptual understanding of electricity were given to these groups, then the likelihood of obtaining a similar pattern of ability in the person measure order table and the location of these students on the person-item distribution map would be fairly similar (Azrilah, 2009).This is also an indication

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that this instrument is capable of categorizing and distinguishing the level of conceptual understanding of the students.

Table 2: Summary Statistics for 102 students.

	Total score	Count	Measure	Model Error	Infit		Outfit	
					MnSq	Zstd	MnSq	Zstd
Mean	15.8	34.0	-0.20	0.45	1.00	0.0	0.95	0.1
SD	5.5	0.0	1.08	0.05	0.21	1.0	0.35	0.5
Max	31.0	34.0	3.40	0.72	1.50	2.0	1.99	1.4
Min	5.0	34.0	-2.67	0.42	0.54	-2.0	0.33	-0.8
Real RMSE .47 True SD .97 Separation 2.06 Person Reliability .81 S.E. of Person Mean = .11 CRONBACH ALPHA (KR-20) Person RAW SCORE "TEST" RELIABILITY = .82								

For the first set of data (Table 1), it can be seen that the mean infit and outfit for item mean square is 1.00 and 0.95 respectively which is very much as the expected value of 1.00 (Linacre, 2011), as stipulated by the quality criteria. Similarly, the mean infit and outfit person mean squares are both at 1.00 and 0.95 respectively (Table 2). The mean Z standardized infit and outfit values are expected to be 0.0. As displayed in Table 1 and 2, the mean infit and outfit values for the item Z-standard are 0.0 and -0.1 while the mean infit and outfit for the person Z-standard are 0.0 and 0.1. Since the values for the mean square and the Z-standard are close to the expected values, it can be said that the data for the actual research do fit the Rasch model reasonably well and the analysis conducted reflected the outcome of this research.

Table 1 and 2 also presented the data needed for targeting. The item difficulties range from -4.18 logit (SE=0.60) to +5.06 logit (SE=1.02) while the students ability range from -2.67 logit to +3.40 logit. As can be seen in Figure 1, the spread of items of +9.0 logit matched the students' ability range of +6.0 logit. In other words, the distribution of the items is large and sufficient to measure the students' understanding of electricity. Overall, the targeting of the items to the students is good.

In this study, the information related to the students' conceptual understanding of electricity especially resistive parallel circuit are gathered from their responses given to the items dealing with all the topics related to electrical current, voltage, and resistance, ability to recognize and connect parallel circuits together with the ability to solve parallel resistors problems. In order to assess the students' level of conceptual understanding on electricity, it is necessary to look at the results of the analysis. From their responses of every section in the instrument, the students' level of conceptual understanding on electricity especially parallel resistors can be deduced. The first analysis to look at is the students' statistics. The mean obtained for these students is μ_{Person} = -0.20 logit. Since this value is negative, it can be confidently said that the 34 items in PCCUT were quite challenging for these respondents since the mean value for item, μ_{item} = +0.00 logit is slightly higher than μ_{Person} = -0.20 logit. By referring to Figure 1, it can be shown that 35% of the students are located above the item mean indicating that 35% of the students' ability are located above 0.00 logit while 65% are found below the item mean, meaning that in general 65% of the students ability are below average.

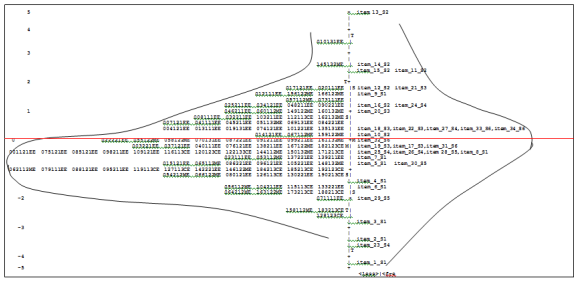

Fig. 1: Person-Item Distribution Map.

Table 3 displays the hierarchical ranking of the items difficulty level starting with the most difficult item which is item 13, relating to the topic of current to the least difficult which is item 1 (on parallel circuit diagram). From a total of 34 items, 47% are situated above the item mean of 0.00 logit and the rest 53% are below the item mean. There are 5 items which has a measure above +1.83 logit, indicating that these items are very difficult. On the other hand, 7 items has a measure below -1.40 logit, signifying that these items are very achievable for the students.

Discussion and Conclusion:

Overall, the students' responses to the 34 items in PCCUT has shed some findings regarding their areas of difficulties in the area of electricity particularly the parallel resistors. Below are the results and diagnosis of each

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domain in the instrument. First of all, the students found that Section 1 (area of circuit diagrams showing parallel arrangements of resistors) to be the most unchallenging area since quite a few of them were successful in identifying the correct arrangements of the resistors in circuits. However, some of the students were experiencing difficulties when they encountered the combined circuits where the arrangements of parallel and series circuits existed within one complex circuit. Only 25% of these students answered successfully. In addition, these students were at ease drawing circuits (series and parallel) when asked to do so in Section 5. They were more confident in identifying the series circuits compared to the parallel ones.

Table 3: Measure Order of Items.

Item no.	Score	Measure	Model S.E	Infit		Outfit		PtMeaCorr	Topic
				Mnsq	Zstd	Mnsq	Zstd		
13	1	5.06	1.02	1.04	0.4	0.42	-0.2	0.14	current
14	9	2.59	0.37	0.91	-0.2	0.58	-0.8	0.40	current
11	10	2.45	0.36	1.26	1.0	1.60	1.2	0.09	current
15	10	2.45	0.36	0.94	-0.1	0.68	-0.6	0.38	current
12	16	1.83	0.30	1.13	0.8	0.95	-0.1	0.29	current
21	17	1.74	0.29	1.04	0.3	1.06	0.3	0.33	voltage
9	20	1.51	0.27	0.90	-0.60	0.79	-0.7	0.47	Combined circuit
24	24	1.23	0.26	1.32	2.2	1.58	2.2	0.11	resistance
16	26	1.10	0.25	1.21	1.6	1.51	2.1	0.20	current
20	27	1.04	0.25	0.92	-0.60	0.84	-0.7	0.48	voltage
34	37	0.48	0.23	0.75	-2.8	0.66	-2.6	0.65	Problem solving
18	38	0.43	0.23	1.01	0.1	0.97	-0.1	0.43	voltage
22	38	0.43	0.23	1.11	1.1	1.15	1.1	0.34	voltage
27	38	0.43	0.23	1.19	1.9	1.36	2.3	0.25	resistance
33	40	0.32	0.23	0.77	-2.7	0.7	-2.3	0.63	Problem solving
10	43	0.17	0.22	1.07	0.8	1.04	0.4	0.38	current
32	48	-0.07	0.22	0.79	-2.6	0.73	-2.3	0.61	Problem solving
17	49	-0.12	0.22	1.01	0.2	1.00	0.0	0.43	voltage
19	50	-0.17	0.22	0.90	-1.1	0.84	-1.3	0.52	voltage
31	50	-0.17	0.22	0.83	-2.0	0.77	-2.0	0.58	Problem solving
25	53	-0.32	0.22	1.10	1.20	1.10	0.8	0.35	resistance
28	54	-0.36	0.22	1.03	0.4	0.98	-0.1	0.41	Circuit connection
8	56	-0.46	0.22	1.01	0.1	1.04	0.3	0.41	Combined circuit
26	56	-0.46	0.22	1.35	3.8	1.83	5.0	0.10	resistance
7	59	-0.61	0.22	0.93	-0.9	0.87	-0.9	0.49	Circuits
5	61	-0.71	0.22	0.86	-1.6	0.82	-1.2	0.53	Circuits
30	63	-0.81	0.23	1.04	0.5	1.06	0.5	0.38	Circuit connection
4	74	-1.40	0.24	0.93	-0.6	0.81	-0.8	0.45	Circuits
6	77	-1.58	0.25	0.98	-0.1	0.86	-0.5	0.40	Circuits
29	83	-1.99	0.27	0.99	0.0	0.84	-0.4	0.36	Circuit connection
3	92	-2.82	0.35	0.85	-0.5	0.76	-0.4	0.37	Circuits
2	96	-3.42	0.43	0.99	0.1	0.78	-0.2	0.22	Circuits
23	97	-3.62	0.47	0.88	-0.2	0.60	-0.5	0.30	resistance
1	99	-4.18	0.60	0.98	0.2	0.70	-0.1	0.18	Circuits
Mean	47.4	0.00	0.30	1.00	0.0	0.95	-0.1		
S.D.	26.6	1.87	0.15	0.15	1.4	0.31	1.5		

Section 2 items, related to the electric current were found to be the most difficult among all the items. The easiest item is item 10 at +0.17 logit which tested students' knowledge and application of the Kirchhoff's First Law and the most difficult item was item 13 at +5.06 logit, which tested students' idea of total current when one of the parallel resistors was removed from the whole circuit. There was only 1 correct response for item 13 (+5.06 logit) given by student of ability measure at +1.32 logit. A thorough check done on his responses to all items in Section 2 relating to electric current shows that this student is well-informed about the behaviour of current particularly when there are changes made to the whole circuit in terms of addition or removal of a load.

Items in Section 3 were found to be challenging as well for the students, even though they were not as complex as items in Section 3. They students were experiencing difficulty in items which involved reducing or adding a similar resistor from the existing parallel circuits. The most difficult item in Section 3 is item 21 (at +1.74 logit) which tested the students' understanding of the potential difference when a similar battery was connected in parallel to the existing one. From the low percentage of correct responses (20% and less), it was obvious that the students were having problems in providing the correct response.

Section 4 items tested the students' knowledge on the application of electrical resistance. Majority of the students had trouble in predicting the amount of voltage across a resistance when another similar resistor was added to the existing one (item 27 at +0.43 logit). However, the students performed very well in the application of Ohm's Law.

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Section 6 was designed to examine students' problem solving skills in basic parallel resistor circuits. The students were to provide some mathematical calculations as their answers to the problem solving tasks given. It is also meant to investigate whether the students are model thinkers by looking at the type of mental models used by the students in their problem solving activities. The students' responses were analyzed based on the correct answer and the methodology. Those who have used circuit models and equations are considered as model thinkers (Vosniadou, 2002). Overall, the items in Section 6 are considered as relatively difficult for these students. Comparing all of students, it can be said that only 56% of them are 'model thinkers'.

By scrutinizing and analyzing the students' responses to each of the 34 items related to electricity particularly parallel resistors, the research then concluded that each of these students can be placed into one of the several categories of logit bands (band 1 to band 6) depending on their conceptual understanding and perspectives for the electricity concepts.

Band	Logit measure	Label as	Traits
1	+2.76 logit to +4.63logit	Exceptionals	exceptional, in-depth understanding and skills of the electricity concepts
2	+1.42 logit –to +2.76 logit	Proficients	capable in handling all electricity related tasks particularly parallel circuitry.
3	+0.00 logit to +1.42 logit	Have some knowledge	well-informed about most concepts of electricity except for some difficult areas in grasping the electric current concept.
4	-0.62 logit to +0.00 logit	Need some improvement	capable of handling easy tasks, have difficulties in handling complex tasks related to the electric current, voltage and resistors
5	-2.08 logit to -0.62 logit	problematic	lacked the basic understanding of electricity and exhibited weakness in most of the tasks performed
6	-4.40 logit to -2.08 logit	Not recommended	Very much lacking in the basic understanding of electricity

Fig. 2: Performance Indicator in logit measure.

By using the instrument (PCCUT) to evaluate the students' conceptual understanding of electricity, focusing on parallel resistors, the results are capable of categorizing a student into a particular profile band. Each band acts as performance indicators providing valuable information regarding the students' conceptions and misconceptions on the areas of electricity. As indicated by the profile bands, it can be concluded that the students who belong in band 1 to band 4 are capable in electricity. Those in band 5 and 6 are not recommended to pursue a specialization in electricity.

In general, this research has shown that the students' academic performance were able to be identified via the instrument PCCUT and using the Rasch Measurement Model. Similar work could be done on other areas of sciences where Rasch Measurement Model can be proposed as a useful tool in forecasting and identifying students' academic performance.

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