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The Use of Rasch Wright Map in Assessing Conceptual Understanding of Electricity

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ABSTRACT

This article examines the usage of Rasch Wright map in evaluating students' conceptual understanding of electricity. A questionnaire, Parallel Circuit Conceptual Understanding Test (PCCUT), was developed for this purpose. The 34 items PCCUT was administered to 102 local engineering, university students. The item reliability is very good at +0.97. Findings showed the students experienced difficulties in diagnosing current, voltage and resistance when presented with a circuit involving the removal of a resistance or the addition of a battery. Additionally, they had problems in identifying parallel circuits in a combined arrangement. On the other hand, majority of them had no difficulty in recognising individual series and parallel circuit as well as circuit connections. Thus, it can be said that the Wright map was very useful in assessing the students' conceptual understanding of electricity.

Keywords: Conceptual understanding, electricity, Rasch Model, Wright map

INTRODUCTION

Electricity involves understanding of current, voltage, resistance and other important electrical concepts. It also deals with complex and highly abstract concepts which are quite impossible to visualise (Mulhall, McKittrick, & Gunstone, 2001). Students are required to learn concepts such as closed loop, current attenuation, role of bulb (resistance), direction of current and sequential inference model (Chiu & Lin, 2005). The key to understanding circuits is creating and interpreting circuit diagrams (Marshall, 2008). According to Marshall, the pre-requisite skills that one must have

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in solving any electrical tasks are the capability in recognising electrical symbols representing the devices, reading and encoding the circuits. These enable them to acquire good circuit identification skills and to be able to connect the circuit correctly. Students find topics related to parallel circuitry combined with the concepts of current, voltage and resistance to be the most challenging (Ipek & Calik, 2008).

BACKGROUND OF STUDY

In the field of science, a diagnostic instrument is a common tool in assessing the student's understanding of various topics (Bain, Moon, Mack, & Towns, 2014; Streveler, Miller, Santiago-Román, Nelson, Geist, & Olds, 2011; Shi, Wood, Martin, Guild, Vicens, & Knight, 2010). Important information could be gathered from these diagnostic instruments. Thus, Rasch Measurement Model has been chosen over other approaches since it is capable of assessing the functions of items in the questionnaire and the student's ability simultaneously (Chang & Engelhard, 2016). In addition, very few studies have utilised the Wright map to identify the student's conceptual understanding in relation to item difficulty level. Hence, this research will discuss the outcomes via the Wright map before discussing the findings. A few suggestions will be included in helping the students to gain better insights into the topic of electricity.

Objective of the Study

The objective of this research is to assess the students' conceptual understanding of electricity by means of the Wright map.

METHODS

The Parallel Circuit Conceptual Understanding Test (PCCUT) questionnaire of 34 items was administered to 102 engineering students to measure their conceptual understanding of electricity. Data was analysed using Rasch Analysis Software (WINSTEPS 3.71.0.1).

Respondents

Random sampling technique was used to conduct this survey. Respondents were engineering students at a local Malaysian university selected based on their knowledge of the survey topic.

The instrument

The 34-items PCCUT has six (6) sections:

Section 1 – Meaning of parallel: items 1 to 9.

Section 2- Practical Knowledge of Current: items 10 to 16.

Section 3 – Practical Knowledge of voltage in parallel circuit: items 17 to 22.

Section 4- Practical Knowledge of Resistance: items 23 to 27.

Section 5- Practical Knowledge of circuit connection: items 28 to 30. Section 6- Mental Model: items 31 to 34.

Rasch Measurement Model

The Rasch Measurement Model shows the relationship between a person and an item based on a mutual latent trait. It can predict the likelihood of a person of a given capability to correctly respond to an item of a certain level of difficulty. The probability of success depends on the difference between the ability of the person and the difficulty of the item (Bond & Fox, 2015). The Rasch Measurement Model is based on two fundamental theorems:

- 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 influences the person's responses while the person's ability is the attribute that influences the item difficulty estimates (Linacre, 1999). The relationship of a person and an item could be predicted based on a common scale (logit). The software used in Rasch Model, WINSTEPS version 3.71.0.1, is able to chart both the person and item position. Rasch modelling assembles a linear measure from the ordinal scores obtained (Sick, 2009). The measure of goodness of fit can be seen from the arrangement of both items and persons along a continuum (range). This Wright map depicts the items arranged according to the levels of difficulty on one side of the band and the persons positioned according to the level of competency on the other side (Kay, Bundy, & Clemson, 2008; Jacobs, Mhakure, Fray, Holtman, & Julie, 2014). In a Wright map (look at Figure 1), the vertical dashed line represents the ordering of the persons and items from less to best (bottom to top). The items are situated on the right and arranged from the easiest (bottom) to the most difficult (top). As for the persons, the ordering goes from the less smart (bottom) to the smartest (top of the vertical line). At the centre of the vertical line is the letter "M" which denotes the mean for the item and the persons. The letter "S" reflects one standard deviation away from the mean value while "T" indicates two standard deviations away from the mean value. In Rasch model, the scale has been set to zero for the item mean when a person has a 50:50 likelihood of answering successfully (Saidfudin, Ghulman, Razimah, & Rozeha, 2008). The person is more likely to respond correctly to an item lower on the scale than his ability and less likely to correctly answer an item higher on the scale.

RESULTS

An appraisal of data fit to PCCUT was conducted as a way of observing the extent that the students' responses to each item are consistent with responses to other items on the assessment (Smith, 2005).

Item and Person Reliability

Table 1 presents the overall statistics of the instrument with 34 items.

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								

The results showed that PCCUT produced 'excellent' item reliability (Fisher, 2007) of +0.97.

Table 2 shows the summary statistics of respondents.

Table 2
Summary statistics of respondents

	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								

The Person reliability is identified as 'good' at +0.81 by Fisher (2007). In addition, the Cronbach Alpha (KR-20) Person Raw score test reliability is slightly higher at +0.82. With the reliability at +0.82, if a similar set of instrument measuring the conceptual understanding of electricity was given to these groups, the likelihood of obtaining a similar pattern of ability in the person measure order table and the location of these engineering students on the Wright distribution map would be similar (Azrilah, 2009). This also indicates that this instrument is capable of categorising and distinguishing the level of conceptual understanding of the respondents.

Student performance in PCCUT according to the Wright Map

The mean obtained 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 observing the items on the right of the map and taking note that the items above the mean value (the red line) are the more difficult ones, it can be said that the 34items can be categorised as easy and difficult, based on their location on the map.

Easy items

- Items 1 to 8, which are located below the mean value, are the easiest items for the students to endorse. This is an indication that majority of the students had no difficulty in identifying the circuits drawn in parallel form.
- Items 28, 29 and 30, which are items dealing with series and parallel circuit connections, are also located below the mean value. Hence, this shows that the students had no problem in recognising circuits connected in series or parallel.
- Item 23 appears to be the second lowest item on the map. This means that the item is also easily endorsed by the students. This is not surprising because item 23 deals with the Ohm's Law which requires them to perform calculation using the equation $V=IR$.

Difficult items

- Item 9 was located high at +1.51 logit above the mean value. It was considered difficult for the students because the circuit had series resistors connected in parallel to another resistor. The students were not able to identify the parallel junction within the combined circuit.
- Items 10 to 16 were situated on the top part of the map, indicating that majority of the students were unable to endorse these items. This was especially true for item 13 which happened to be at the top part of the map. Item 13 dealt with the reading of the existing ammeter when one of the parallel resistors was removed from the circuit.
- Items 18, 20, 21, 22 related to the concept of voltage were also considered difficult. They measured the student's ability to estimate the reading of the voltmeter when one of the parallel resistors was removed. Similar to the concept of current, the students were not able to conceptualise the concept of voltage.
- Items 24 was considered challenging because the students did not have enough knowledge in predicting the change of current when a similar resistor was added parallel to the existing one.

- Similarly, item 27 was considered difficult since 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.
- Items 33 and 34 were circuits drawn differently from the conventional circuits. There were no rectangular boxes joining the resistors in parallel; instead, curvy lines were used. The diagram might have confused the students.

DISCUSSION

The Wright map showed that the PCCUT has a good range and is well targeted with respect to the persons' measure distribution. The items are distributed from the most challenging (top right of the map) to the least challenging (bottom right of the map). The students with high ability (high conceptual understanding) in electricity were situated in the upper left quadrant of the map. On the other hand, those with low level of conceptual understanding in electricity were located in the bottom left quadrant. A student having the same logit measure as an item is said to have a 50:50 chance of answering the item correctly. However, if the items are at a higher difficulty level than the person's logit measure, then this means that the student has less probability (less than 50%) of endorsing that particular item. Similarly, if the student's ability measure is higher than the items difficulty measure, it shows that the student has a higher chance (more than 50%) of endorsing that item correctly.

As can be seen from the map (Figure 1), majority of the items which are related to the recognition of parallel circuit (Section 1), circuit connection (Section 5) and a few items of the mental models (Section 6) are situated below the average value (0.0 logit).

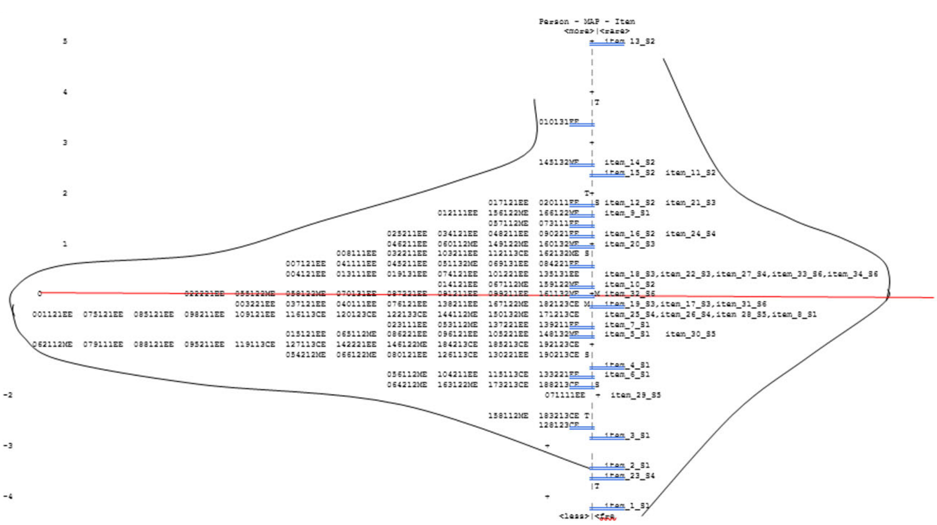

Figure 1. Rasch Wright map

This shows that the students have good conceptual understanding of these topics.

Items related to the concept of current, voltage and resistance were situated above the +0.0-logit mark. In addition, quite a few are situated high above this mean value, with very high logit measures. This means that these items are very challenging to the students. They experienced difficulties in solving these types of items. Item 13 of Section 2 has the highest logit measure among the items, which means it is the most difficult item to endorse by the student. A check on the student responses to item 13 showed that only 2 out of 102 students answered correctly.

CONCLUSION

In this study, the Wright map is the key source of data. The map is indeed the heart of the analysis since it is able to display the location of the easily endorsed items and the least likely to be endorsed items on the same map. Thus, the level of conceptual understanding of each student in electricity can be identified by comparing the location of each student's logit measure to the location of each item.

It can be deduced that the respondents had a sound conceptual understanding of the concept of parallel circuits, circuit connections and mental models. However, their conceptual understanding of the concepts of current, voltage and resistance is not so encouraging. Further investigation on the items revealed that the students faced difficulty in interpreting the values of current and voltage involving the removal of a resistor and the addition of a battery in the circuit.

One way to address this is to provide continuous 'hands-on' activities in the electricity lab whenever these electricity concepts are taught. The exposure to the real live circuit during the removal of a resistor from a parallel circuit and the addition of a battery in a whole circuit will enable the student to observe the situation themselves and therefore enhance their level of conceptual understanding.

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