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Calibration of the science process skills among Malaysian elementary students: A Rasch model analysis

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Article Info	ABSTRACT
	This study aimed to calibrate the test items of science process skills used as a test at primary school students to provide information on the difficulty of each item. Data were collected from 128 standard five students in a primary school in Penang. The test was given in multiple-choice as many as 40 items consisting of 33 items partial credit test was developed to gather information from the students. The analysis included an assessment of the model's assumptions and calibrations according to the individual items. Information on the Rasch calibration according to the topic were provided. Results revealed that the measurement made fulfilled both model-data fit and unidimensionality assumptions. Further analysis showed that observing and communicating were endorsed as the easiest to master while inferring and classifying were the most challenging. The study discussed the implication, particularly towards the teaching and learning of science process skills in the classroom. Teachers should seriously consider the science process skills when designing their teaching and learning strategies in the classroom.

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1. INTRODUCTION

Science process skills are defined as a set of skills using scientific processes and approaches [1]. The skills consist of two basic skills, which are basic science process and integrated science process. Basic skills are composed of the skills of observing, classifying, measuring using numbers, inferring, predicting, communicating, and using space-time relationship [2]. Meanwhile, integrated science process skills combine one or more basic science process skills in one skill. There are five science-based skills in the integrated science process: data interpretation skills, operational definition skills, variable control skills, hypothesis-making skills, and practical skills [3]. These skills can improve students' performance in terms of their ability to help students in the learning process and facilitate students to discover scientific methods in problem-solving [4]. Science process skills are also investigated with regards to other related constructs such as critical thinking [5], [6], creative thinking [7], and problem solving skills [8].

In Malaysia, science process skills are referred in multiple terms such as scientific methods, scientific thinking, critical thinking, and problem-solving [9]. These skills are important in science education as it acts as a necessary tool in learning and understanding the science. Science learning through science process skills was expected to be a vehicle for students to learn about themselves and their natural surroundings and the further prospect of applying science process skills in their daily lives [10]. According to the Malaysian curriculum, the objective of acquiring the science process skills is to help students to be able to

ask a question and find the answers in a systematic approach [11]. These skills act as a bridge to connect between previous experience and new experience by organizing and linking the acquired knowledge. Previous studies on the science process skills were abundance. In their qualitative studies, Rauf, *et al.* [12] revealed that the process of teaching and learning science that uses various teaching approaches in one science lessons has additional advantages in terms of providing opportunities for the inculcation of science process skills. Research also conducted to investigate demographic variables such as gender, ethnicity, and school location on the science process skills [13], [14]. There were also studies related to development of instrument to measure science process skills [15], [16].

However, recent studies found that these skills were not yet fully mastered by students. For example, students did not become familiar with important terms in science process skills such as inference, control variables, and interpretation of data [17]. One of the reasons students' weaknesses in mastering these skills were students has trouble distinguishing between inferential skills by hypothesizing and interpreting data. This is because these three science process skills are among the most difficult to understand. Many students find it difficult to distinguish between inference skills and hypothesis-building skills. Pupils tried to relate a hypothesis to the title or purpose of an event or phenomenon. Students need to be able to distinguish between these three skills as these skills are important before students can draw any conclusions in an experiment. Besides, students are weak in mastering integrated science process skills and have difficulty answering those skills. Integrated skills include data interpretation, operational definition, variable control, hypothesis, and experimental skills [18].

Other than that, studies found that students did not understand the concepts of science process skills. The problem occurred because students only focus on the procedure provided in the textbook. Instead, students need to provide their methods to conduct experiments based on students' understanding of the concept [19]. If students do not understand this concept, then the skills of this scientific process cannot be adequately applied. Mastery of scientific skills is essential for a better understanding of the concept of science in the process of the scientific process. Science process skills are fundamental for every student to practice scientific methods in developing science and are expected to acquire new knowledge or develop the knowledge that has been owned [20]. Learning exercises development will enhance their academic achievement on basic and integrated science process skills [21]. The novelty in this study is based on the calibration science process skills among Malaysian elementary students using a Rasch model analysis in Malaysia [22]. Therefore, this study analyzes the science process skills and suggests that teachers should seriously consider the science process skills when designing their teaching and learning strategies in the classroom. These research objectives are mainly focusing on teaching and learning science process skills in the classroom.

2. RESEARCH METHOD

A sample of 128 elementary students (average age=11 years old) engaged in the present study employing the purposive sampling framework. The framework was used to maintain an equal proportion of high, moderate, and low ability students. The participants consisted of 66 males (51.56%) and 62 females (48.44%) from schools in Penang in the northern part of Malaysia.

2.1. Instrument

In this study, the science process skills were measured using a 73-item self-developed mixed-format test. There were 40 multiple choice (MCQ) and 33 partial credit items in the test. In the MCQ, the students chose an answer from the list of four possible alternatives. One mark was awarded for the correct answer, while no mark was given for the incorrect one. Meanwhile, in the partial credit format, the students were asked to construct their answers. The number of marks awarded was between one and two marks, based on the number of steps needed to answer the item.

2.2. Data analysis

This study employed the Rasch model measurement framework using the Winsteps 3.74 software to analyze the data. The framework was preferred since it affords better measurement precision of the unobservable construct, such as the science process skills. In this analysis, the Rasch model transformed the respondent's raw score into an equal-interval unit of measurement (as in a ruler) called logits score in a calibration process. Consequently, two critical parameters in measurement, the item difficulty measure, and the respondent's ability measure, were estimated and placed on a common scale with equal-interval properties. Nevertheless, consistent with the purpose of this study, we only focused on the item note that the equal-interval property from the logits score was essential since it did not only provide identification of the differences in respondents' competency but also demonstrated how much the differences is. An in-depth

explanation of the equal-interval measurement property was beyond the scope of this manuscript. Still, those interested can refer to the original description [23] or the more current work. According to Boone [24], the probability of an individual to answer a correct response of an item depends on the individual ability and the item difficulty level. The higher individual ability has the highest probability to answer all items. In contrast, less difficult items have a high probability of getting the correct response from all respondents when the differences between item difficulty and individual ability are monitored [25].

With regards to the data analysis, firstly, we evaluated the empirical data against two fundamental assumptions of the Rasch Model, namely, the model-data fit and the unidimensionality [26]. Examination of model-data fit helped to identify discrepancies between the model's expectation and the data collected. It was to ensure the quality of measurement – in which the measurement could capture the intended construct while keeping the unintended constructs in a reasonable proportion. In this study, the model-data fit was examined using the guideline by Bond and Fox [27]. The data was considered to meet the Rasch model's expectation if the values of the infit and outfit mean-squares (MNSQ) statistics for every item are between .6 to 1.4 logits [28]. Items outside the values were considered measuring too much some unintended construct of 'noise' and not suitable to measure the science process skills.

Meanwhile, the unidimensionality assumption demands that the test items measure only a single construct, that is, the science process skills. In this study, the assumption was examined using the guideline provided [29] in which the percentage of explained variance should be more than 40%. After evaluating the assumptions, we focused the analysis on the calibration of each item according to the Rasch logits scale.

2.3. Research design

The present study was conducted under the descriptive design; in which the focus is to describe the characteristics of items ordered according to the Rasch calibration of the science process skills among Malaysian elementary students. The study implemented cross-sectional survey design. A cross-sectional survey design allows data to be gathered from selected individuals at one time [30]. Besides, a cross-sectional design provide valuable insight into current behavior, attitudes and beliefs in a population [31].

2.4. Research procedure

In this research, the instrument was administered as the high-stake year-end test in the schools. The time allocated for the students to complete the test was one hour and 15 minutes. The teachers provided scores of the students. The scores for each item were recorded into an electronic database and later analyzed using the software. The ethical standards and procedures were carefully followed throughout the study, including ensuring the confidentiality of the data.

3.   RESULTS AND DISCUSSION

Table 1 (see appendix) presents the item difficulty statistics measure and its corresponding standard error, infit, and outfit MNSQ for each item. The infit MNSQ values for all 73 items ranged from .76-1.28 logits, while outfit MNSQ values ranged from .61 to 1.40 logits which are within the intended values of .6 to 1.4 logits [32]. The result confirmed that the test items met the Rasch's model-data fit expectation. Meanwhile, the aspect of unidimensionality is critical in determining something the instrument can measure in one direction and one face. Results showed that the explained variance by measures and persons was 48.8%, which is more than the intended 40%. Hence, the unidimensionality assumption was also met.

With regards to the individual item, the students confirmed that Item 55 (inferring) was the most difficult-to-master item (item difficulty measure=3.35 logits, SE=.51 shown in Figure 1. The item was a one-mark partial credit item and measuring the inferring skills in the topic of heat. A possible answer for this item is given as: i) The water receives heat energy; and ii) The water temperature increases.

Based on the students' answers, many of them did not even attempt these items. Another popular inaccurate answer was "the water boils". This was an observation rather than inferring. One possible explanation of why this item was considered difficult was that the students could not differentiate between responding and manipulated variables.

The students also agreed that Item 71 (controlling variables) was also a difficult item (item difficulty measure=2.55 logits, SE=.28) as shown in Figure 2. It was also a partial credit item with two marks. High ability students could identify that the manipulated variable in this item is the number of bulbs while the responding variables were the light of the bulbs. According to the teachers, the student could not answer the item correctly because they did not have sufficient comprehension of the conceptual understanding regarding the responding and manipulated variables. Nevertheless, we did not rule out the possibility that the students were confused by the item. Some may believe that items from the left column must match all the items in the right column. It is a typical instance where the format of an item may decide its difficulty.
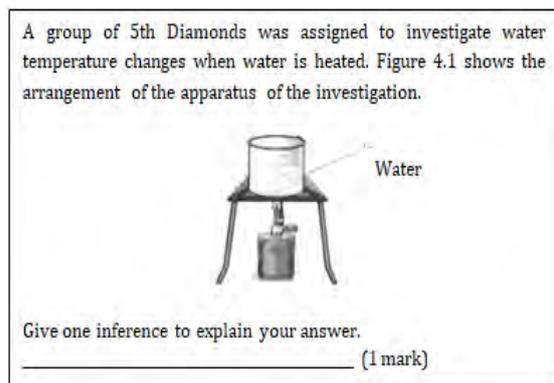
Figure 1. Item 55 (inferring)
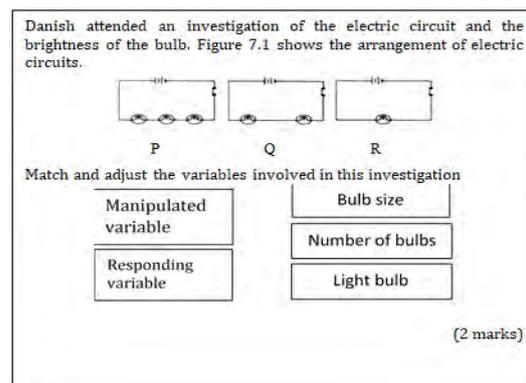
Figure 2. Item 71 (controlling variables)

Apart from the item difficulty measure, we also reported scale difficulty across all science process skills. This information was valuable to identify which science process skills are considered difficult to master by the students. As shown in the following Table 2, based on the highest mean of the item difficulty (i.e., the more difficult) the students confirmed that inferring is the most difficult skill to master (mean=.68 logits, SD=0.24 logits) followed by classifying (mean=0.61 logits, SD=0.25 logits) and interpreting data (mean=0.55 logits, SD=0.19). In contrast, based on the students' response, communicating was acknowledged as the easiest-to-master science process skills (mean=-1.75 logits, SD=0.24) and followed by observing (mean=-0.55 logits, SD=0.22) and measure using number (mean=-0.20 logits, SD=0.19).

Table 2. Science process skills – scale difficulty in logits

Science process skill	No. of item	Mean	Standard deviation
Inferring	9	0.68	0.24
Classifying	8	0.61	0.25
Interpreting data	7	0.55	0.19
Predicting	10	0.33	0.21
Using time-space	1	0.17	0.20
Experimenting	5	0.0080	0.20
Hypothesizing	4	0.0025	0.20
Define operationally	8	-0.045	0.21
Controlling variables	4	-0.17	0.22
Measure using number	1	-0.20	0.19
Observing	12	-0.55	0.22
Communicating	4	-1.75	0.24

3.1. Discussion

This study reported that communicating and observing skills were the easiest items for students to answer. One possible reason was that these two basic science process skills were always considered working concurrently [33]. For example, students need to communicate so that they can share their observations with others. It is also worth noting that observing and communicating are also requisite for advanced science process skills. Measuring, for example, is defined as the process of assigning numbers to a particular construct. Therefore, when a student says that the length of a book is 25 cm, he or she is communicating how much length the book he/she observed. Thus, measuring is sometimes regarded as the quantitative observation and communication of a construct. We recognized the findings as positive since students require a high level of communication and compliance in various science-related activities such as retrieving information from the library or electronic database, doing a scientific reading from articles and textbooks, listening and observing lecture and demonstration, writing scientific reports, representing information through tables and graphs, as well as the presenting knowledge via briefing or oral conferences [34].

In contrast, the students confirmed that classifying and inferring were the most difficult-to-master science process skills. The results were rather disturbing since the capacity to classify is usually associated with the ability to understand similarities, differences, and interrelationships. Understanding these inter-related skills is imperative in understanding different objects and events in science. Meanwhile, inferring is related to the ability to make a logical explanation from observation. It should be noted that a single observation may result in different inferences.

Furthermore, to reinforce the inferences, the students might need to make an additional observation of a particular event. Students might also reinforce their inferences by relating the event with their experience. It may explain why these two science process skills were considered as complicated by the students. As for teachers, they should know that teaching students to make logical inferences is a strenuous business. Hence, teachers need to make the process as explicit as possible by asking how and why questions. It is imperative to reflect on how they communicate their answer [35], suggested active learning using discussion, brainstorming, open inquiry laboratories, lectures, and presentations as practical techniques to nurture students inferring skills [36].

Several limitations bound this study. First, although the test items used in this study was carefully developed to measure specific science process skills, it only represented some limited sample of behavior or stimulus. So, there is a necessity to conduct similar studies to a comparable sample of students. It is to ensure that more information is gathered primarily in looking at the trends and differences in the basic science process skills. Second, even though it was possible to measure each process skill, researchers argued that all the skills were integrated when scientists designed and carried out experiments [37]. Hence, measuring the basic science process skills through experiments or demonstrations may provide more information on integrating these skills [38]. This, in turn, will help teachers to teach basic science process skills more productively. Third, this study was limited since it focused on basic science process skills only.

Nevertheless, to be successful in science, students need other skills as well [39]. A study that models necessary science process skills with other skills such as process skills, attitudes, or dispositions may also provide relevant data, especially how one skill inspires others. This knowledge is worthy to promote teaching and learning, making science more engaging and congenial [40].

4. CONCLUSION

The Rasch model is feasible to identify learning difficulties of science process skills. Results from the present study revealed that the measurement made fulfilled both model-data fit and unidimensionality assumptions. The item-level analysis showed that observing and communicating were endorsed as the easiest to master while inferring and classifying were the most challenging. The science processes skills are best taught hand-on science such as create more activities, experiments, and projects. Teachers should seriously consider the science process skills when designing their teaching and learning strategies in the classroom.

However, findings from the present study are limited in terms of generalization since the study involves only one cohort of students. For the future study it is recommended to conduct similar study with broader sample of students so that more samples of science process skills can be calibrated and therefore provide more refine information about the science process skills. Its limit notwithstanding, in general, the present study is able to identify the easy and difficult-to-master science process skills that maybe helpful to teachers.

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APPENDIX

Table 1. Item statistics according to science process skill

Item	Topic	Science process skills	Measure	SE	Infit MNSQ	Outfit MNSQ
55	Heat	Inferring	3.35	.51	.97	0.62
71	Electricity	Controlling variables	2.55	.28	.97	0.8
57	Energy	Inferring	2.37	.21	1.06	1.00
59	Energy	Interpreting data	2.32	.21	.92	0.83
52	Heat	Define operationally	2.16	.19	.90	1.28
64	Light	Interpreting data	2.16	.19	1.13	1.18
58	Energy	Predicting	2.11	.19	.99	0.91
32	Matter	Predicting	2.09	.32	.97	0.72
7	Life plant process	Classifying	2.01	.30	1.06	1.14
70	Electricity	Controlling variables	1.77	.19	.81	0.78
72	Electricity	Hypothesizing	1.49	.18	.93	0.79
61	Acid and Alkaline	Define operationally	1.34	.18	.91	0.98
60	Acid and Alkaline	Classifying	1,31	.24	.90	0.69
69	Electricity	Predicting	1.29	.17	.84	0.74
24	Heat	Experimenting	1.22	.24	.98	0.97
50	Web chain	Interpreting data	1.19	.17	.76	0.61
65	Light	Controlling variables	1.15	.12	.88	0.83
68	Electricity	Inferring	1.14	.23	.91	0.78
13	Energy	Inferring	1.07	.23	.99	0.88
36	Life plant process	Observing	.96	.23	1.05	1.11
53	Heat	Interpreting data	.91	.16	1.10	1.03
45	Life plant process	Observing	.88	.22	.87	0.83
30	Matter	Define operationally	.86	.22	1.20	1.22
41	Life animal process	Predicting	.81	.22	1.07	1.25
16	Light	Observing	.76	.22	1.11	1.13
62	Acid and Alkaline	Predicting	.72	.14	.84	0.83
73	Electricity	Experimenting	.68	.14	1.02	1.1
23	Electricity	Define operationally	.52	.21	1.15	1.31
20	Electricity	Experimenting	.37	.20	1.07	1.2
39	Energy	Classifying	.30	.20	1.02	1.04
63	Light	Hypothesizing	.19	.20	.97	0.9
4	Life animal process	Using time-space	.17	.20	1.09	1.09
66	Light	Controlling variables	.15	.20	.93	0.86
44	Life animal process	Inferring	.11	.20	1.01	0.97
54	Heat	Predicting	.07	.20	.94	0.88
51	Web chain	Inferring	.05	.14	.80	0.75
46	Life plant process	Inferring	.03	.20	.88	0.82
48	Life plant process	Inferring	.03	.20	.82	0.76
67	Light	Hypothesizing	-.03	.20	.84	0.78
19	Electricity	Observing	-.09	.20	1.27	1.4
47	Life plant process	Predicting	-.16	.19	1.02	0.99
6	Life plant process	Predicting	-.17	.20	1.05	1.05
56	Energy	Measure using number	-.20	.19	1.02	0.97
29	Matter	Observing	-.27	.19	.96	0.94

Table 1. Item statistics according to science process skill *(continued)*

Item	Topic	Science process skills	Measure	SE	Infit MNSQ	Outfit MNSQ
34	Acid & Alkaline	Classifying	-.27	.19	1.09	1.2
9	Energy	Observing	-.31	.19	1.05	1.16
25	Heat	Interpreting data	-.31	.19	1.07	1.32
42	Life animal process	Observing	-.42	.19	1.08	1.07
27	Heat	Experimenting	-.58	.19	1.19	1.28
38	Energy	Communication	-.61	.19	.95	0.95
49	Web chain	Define operationally	-.61	.19	.91	0.84
28	Matter	Classifying	-.69	.19	1.02	1.1
18	Light	Observing	-.73	.20	1.28	1.33
12	Energy	Interpreting data	-.76	.20	1.13	1.13
14	Energy	Classifying	-.80	.20	1.11	1.1
33	Acid and Alkaline	Define operationally	-.80	.20	1.10	1.12
31	Matter	Observing	-1.08	.20	.96	1
35	Life plant process	Observing	-1.08	.20	1.13	1.18
10	Energy	Communicating	-1.37	.22	1.02	1.03
21	Electricity	Predicting	-1.45	.21	1.08	1.15
8	Life plant process	Interpreting data	-1.64	.22	1.04	1.09
17	Light	Hypothesizing	-1.64	.22	1.12	1.35
15	Light	Experimenting	-1.73	.22	1.14	1.04
40	Energy	Define operationally	-1.78	.22	.96	1.06
2	Life animal process	Communicating	-1.88	.23	.95	0.86
26	Heat	Inferring	-1.99	.23	.85	0.7
43	Life animal process	Predicting	-1.99	.23	.86	0.76
37	Energy	Define operationally	-2.05	.24	.80	0.68
3	Life animal process	Observing	-2.16	.24	1.07	1.05
1	Life animal process	Observing	-3.03	.31	1.02	1.00
22	Electricity	Communicating	-3.15	.32	.81	0.63
5	Life plant process	Classifying	-3.26	.34	0.92	0.75
11	Energy	Classifying	-3.51	.37	1.11	1.22
	Mean		0	0.22	1.00	0.98
	SD		1.49	0.06	0.11	0.20
	Minimum		-3.51	0.12	0.76	0.61
	Maximum		3.35	0.51	1.28	1.4